HOW IT WORKS

WHY RUDENESS CAN BE DEADLY!

INSIDE THE HUAWEI P20 PRO

THE NEXT-GEN iPHONE KILLER

HOW IT WORKS

THE MAGAZINE THAT FEEDS MINDS

INSIDE

ENVIRONMENT

JANE GOODALL

CHIMP CHAMPION & CONSERVATION HERO

DISCOVER

The science of pain

How defibrillators restart hearts

Life in the wolf pack

THE TECHNOLOGY BEHIND

SEARCH & RESCUE

HOW EVERYDAY HEROES DIVE INTO DANGER

TACKLING EXTREME CONDITIONS

CAPSIZE-PROOF DESIGN

GPS BEACON TRACKING

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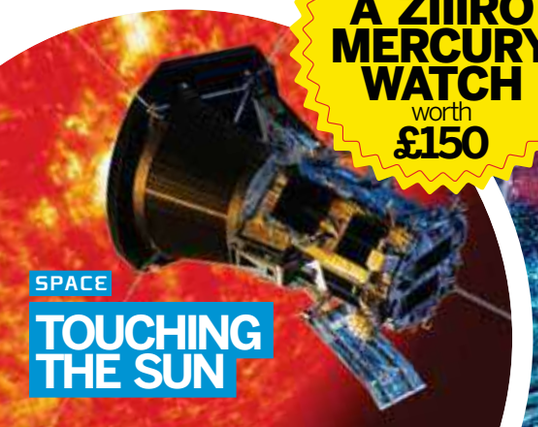

SPACE

TOUCHING THE SUN

ISSUE 116

MYSTERIES OF THE MAYA

The secrets of a lost civilisation revealed

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ISSUE 116

WELCOME

The magazine that feeds minds!

For exclusive **HIW** news and offers, sign up to our mailing list **howitworksdaily.com/newsletter**

Take our latest survey at **tiny.cc/hiwcover18** and you could win a Sphero Mini worth **£49.99!**

Getting lost is a nightmare at the best of times, but when you're out in the open ocean or half way up a mountain and exposed to the unforgiving elements it can be deadly. Search and rescue teams provide a vital service to bring people back to safety, often risking their own lives in the process. Find out how these brave men and women can track you down in your hour of need on page 20.

Also in this issue, we reveal the science of pain, what life is like in a wolf pack and which new smartphone could be considered an iPhone killer.

The team and I value your feedback, and we would really appreciate it if you could spare a few minutes to share your thoughts with us in our latest survey at the link above. With your help, we can make **HIW** better than ever. Enjoy the issue!

Jackie **Jackie Snowden**
Editor

"Pain is more than just a reflex – it helps us remember and avoid harmful activities..."
The science of pain, page 30

Meet the team...

Charlie G
Production Editor
Architects. Mathematicians. Murderers. The Maya were a brilliant and bizarre bunch, and their decline remains a mystery to this day.

Baljeet
Research Editor
NASA launched their historic Parker Solar Probe last month on a mission that will 'touch the Sun'. Find out more on page 68.

Charlie E
Staff Writer
From dogs and drones to lifeboats and helicopters, the UK's brave search and rescue teams use a range of tools to save lives.

Scott
Staff Writer
It's this year's frontrunner as best smartphone, but how is the Huawei P20 Pro using AI to climb to the top? Find out more on page 52.

Duncan
Senior Art Editor
As a huge *Star Wars* fan, I was fascinated to read about Trump's idea for a Space Force. Find out what this might entail on page 62.

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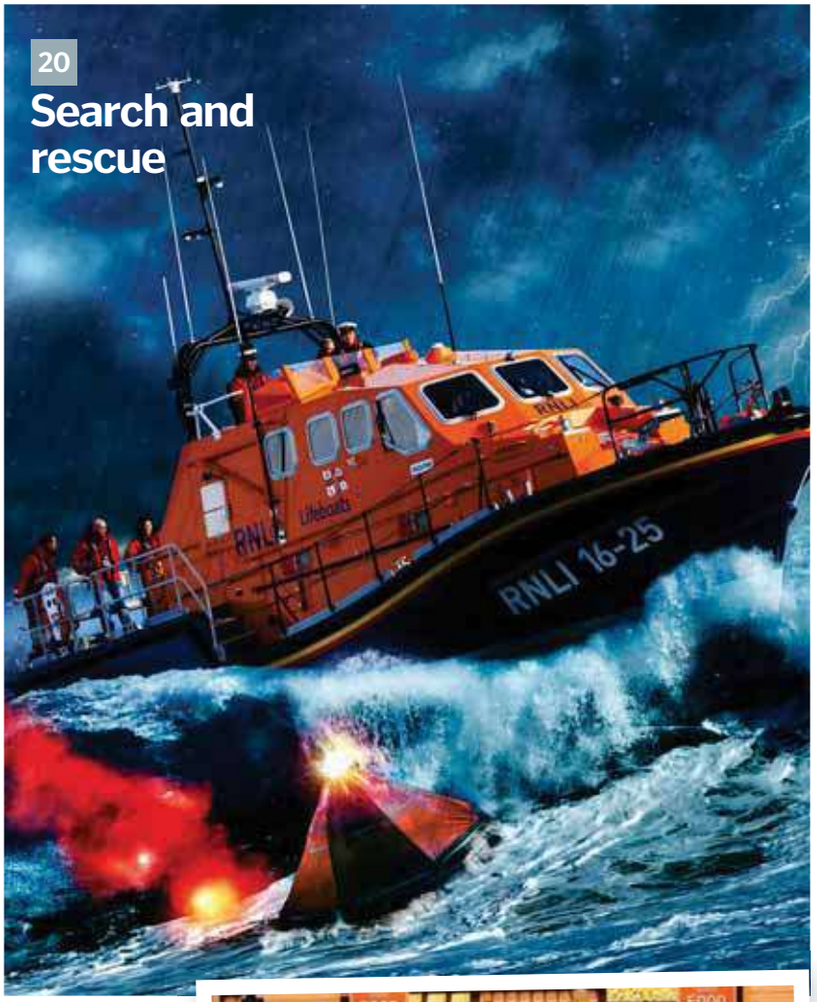
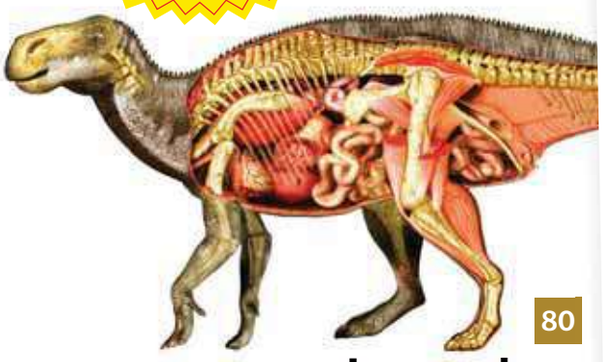


WIN A ZIIIRO WATCH WORTH £150! Page 95



MEET THIS ISSUE'S EXPERTS...

James Horton
Former **HIW** member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.

Jo Stass
Jo has been a writer and editor for over six years. She is particularly interested in the natural world and technological innovations.

Jodie Tyley
The former Editor of **HIW** and **All About History** has tackled many topics in her career, from science fiction to science fact and Henry VIII to honey badgers.

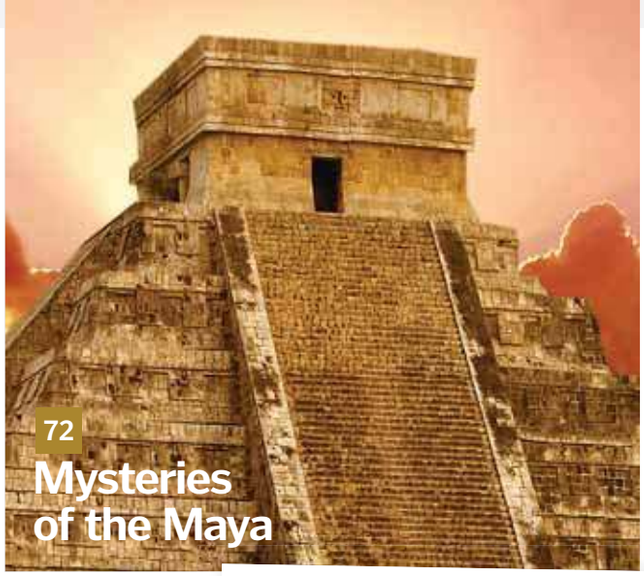
Jonathan O'Callaghan
With a background in astrophysics, former **HIW** and **All About Space** journalist Jonathan enjoys delving into the wonders of space.

Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.

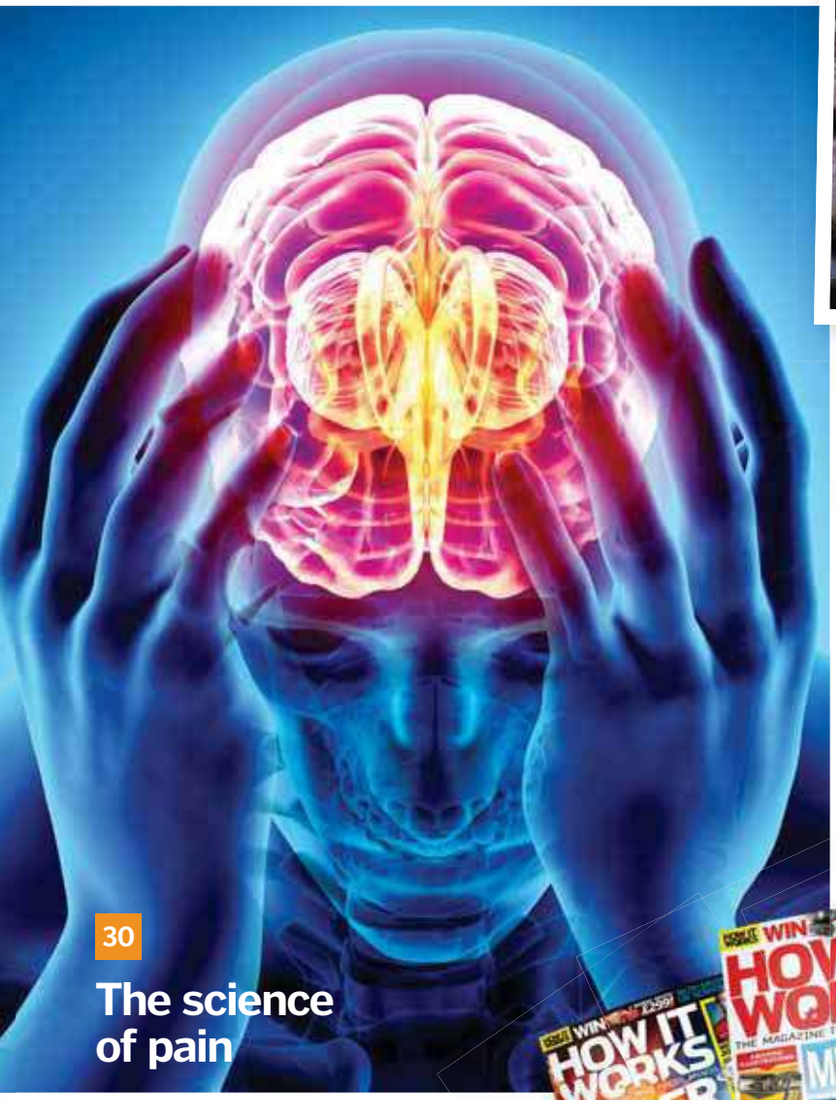
Stephen Ashby
Stephen has been a writer and editor for over seven years. He is endlessly intrigued by technology and Earth science.

Steve Wright
Steve has worked as an editor on many publications. He enjoys looking to the past, having also written for **All About History** and **History Of War**.

Tim Williamson
History Of War
Editor Tim has a passion for all things military but studies and writes about a range of historical eras.



REGULARS

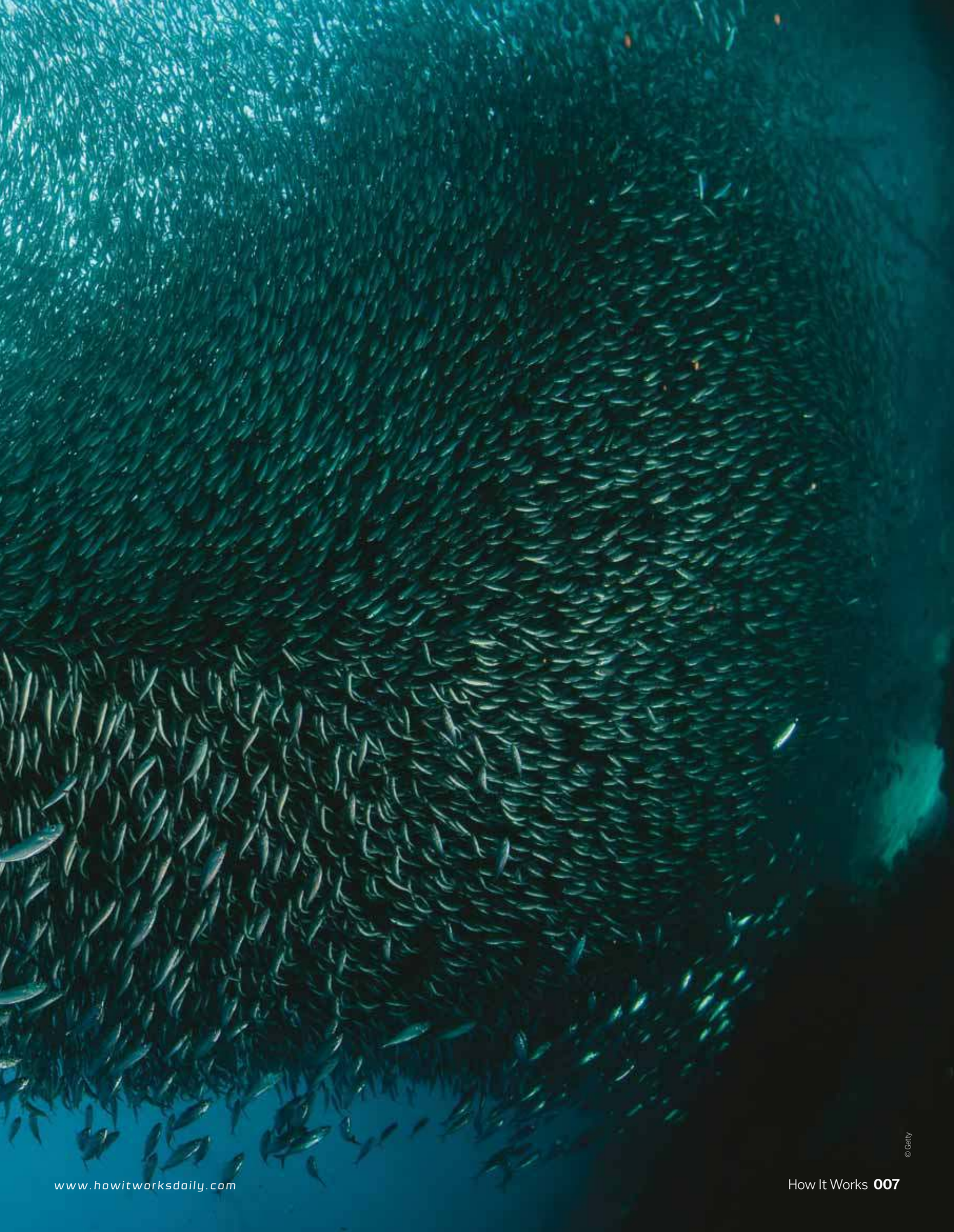


Tom Lean
Tom is a historian of science at the British Library working on oral history projects. His first book, *Electronic Dreams*, was published in 2016.

Victoria Williams
Evolutionary biologist and **World of Animals** writer Vicky is fascinated by the natural world and happiest when she's outdoors.

Back to school

This large school of sardines was pictured off the coast of the Philippines. Many fish species travel together, some in their millions, and synchronise their movements for protection. By moving as one they can confuse would-be predators and also swim and forage more efficiently.



© Getty

Night lights

This nighttime map of Earth, a compilation of satellite data created by NASA, highlights patterns of human settlements across the world. This 'night lights' data can be used by scientists to monitor things like light pollution and urban expansion.

SPACE

Highlights of Bluedot 2018

We returned to our favourite cosmic festival for three nights of live music, hands-on experiments and engaging talks from some of the world's greatest minds

It's no secret that Bluedot Festival is one of the highlights of the **How It Works** calendar, but this year we took a bit of a different approach to it. Taking advantage of Bluedot's free entry policy for children under the age of five, we took along our tiny photography assistant-in-training to see if this festival fusion of science, art and culture really has something to offer the entire family. We were not disappointed! The incredible amount of things to do seems even more exciting when you're looking across a field filled with bubbles and colourful lights from the eyes of a very inquisitive three-year-old. Here are some of our favourite moments from this year's brilliant festival...

Read our full Bluedot debrief at **bit.ly/HIWBluedot**

Jim Al-Khalili and Richard Dawkins

One of the biggest events this year was Jim Al-Khalili, a theoretical physicist, and Richard Dawkins, an evolutionary biologist, in conversation on one of the main stages. The two scientists spoke about the achievements of *Homo sapiens* and our successes in space exploration. We loved the points raised about inclusivity in science. As Dawkins put it, "You don't need to know how to use a Bunsen burner to appreciate the value of science."

Hands-on experiments

From playing with a mysterious non-Newtonian fluid (that hardly acts like a fluid at all) and building viruses made from 3D-printed jigsaw pieces, to digging through sand to find hidden parasitic eggs and experimenting with the effects of black holes using basketballs and a trampoline, there were so many things to explore. It was a great way for kids to interact with scientists and learn through play.

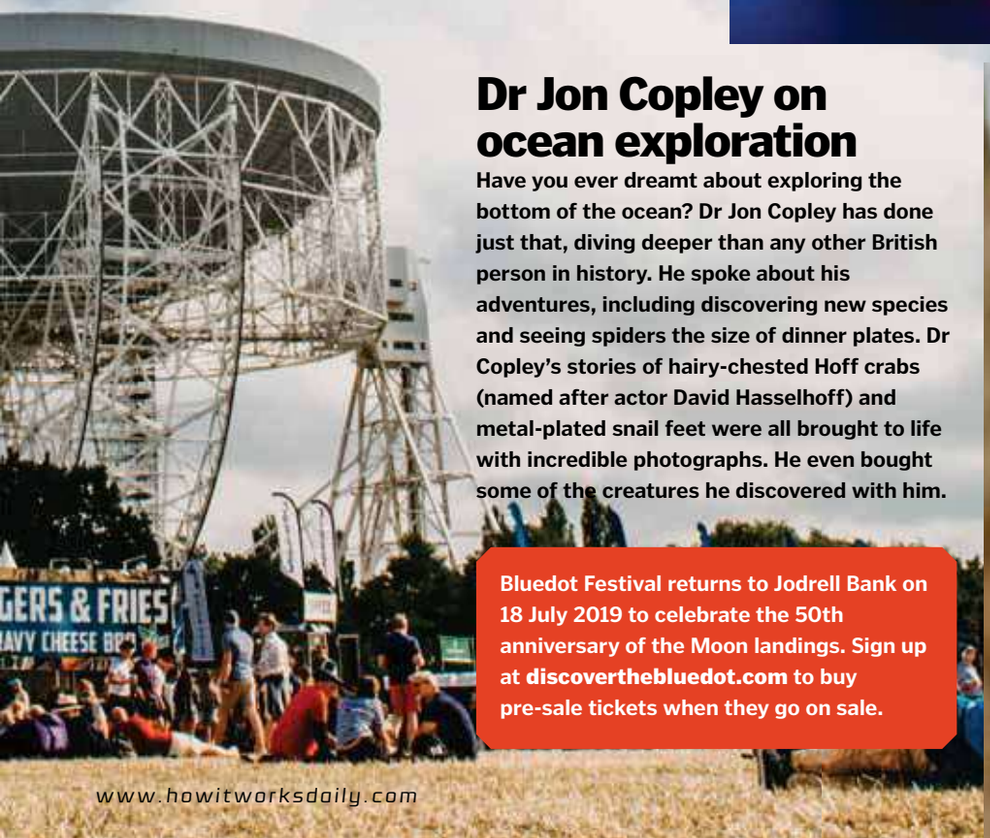
Cornstarch dissolved in water creates a non-Newtonian fluid – a substance that can behave as both a liquid and a solid

Tamed with Professor Alice Roberts

Dr Alice Roberts, an osteoarchaeologist and author, held a fantastic talk at the festival on the animals our ancestors tamed: dogs, cattle and horses. Following the release of her new book, *Tamed: Ten Species That Changed Our World*, Dr Roberts gave an immersive and engaging talk on how these species became essential to the survival and success of our species. We loved learning about how humans went from hunter-gatherers, who hardly impacted on the world around them, to the globe-dominating civilisation we are today.

Pentalum Luminarium

This immersive experience allows you to appreciate colour with a new-found sense of appreciation through a labyrinth of illuminated tunnels and domes. Taking a few minutes to lie down and watch the lights inside the Luminarium was a really calming contrast to the energetic atmosphere outside.



Dr Jon Copley on ocean exploration

Have you ever dreamt about exploring the bottom of the ocean? Dr Jon Copley has done just that, diving deeper than any other British person in history. He spoke about his adventures, including discovering new species and seeing spiders the size of dinner plates. Dr Copley's stories of hairy-chested Hoff crabs (named after actor David Hasselhoff) and metal-plated snail feet were all brought to life with incredible photographs. He even bought some of the creatures he discovered with him.

Bluedot Festival returns to Jodrell Bank on 18 July 2019 to celebrate the 50th anniversary of the Moon landings. Sign up at discoverthebluedot.com to buy pre-sale tickets when they go on sale.

Dr Jon Copley let us get up close to two of the species he discovered, a scaly-foot snail and a shrimp from the Caribbean

ENVIRONMENT

Homo erectus may have gone extinct due to laziness

An extinct species of humans took a relaxed approach to life that may have sealed their fate

Dr Ceri Shipton on site at Saffaqah in central Saudi Arabia where the population was discovered

An excavation of ancient human populations that inhabited the Arabian Peninsula during the Early Stone Age by the Australian National University (ANU) has unearthed evidence suggesting that, when it came to tool making and collecting resources, *Homo erectus* used 'least-effort strategies'. This 'laziness', paired with an inability to adapt to a changing climate, likely played a role in the species going extinct according to lead researcher Dr Ceri Shipton of the ANU School of Culture, History and Language.

"Rather than walk up the hill they would just use whatever bits had rolled down and were lying at the bottom," Dr Shipton commented. "They knew it was there, but because they had enough adequate resources they seem to have thought, 'why bother?'" Dr Shipton expects that as their environment dried out into a desert their techniques for tool making remained the same, which likely contributed to the population's demise.

"There was no progression at all, and their tools are never very far from these now dry river beds. I think in the end the environment just got too dry for them."

SPACE

NASA's launch to the Sun

NASA's Parker Solar Probe launched on 12 August at 03:31 EDT and is now hurtling towards the Sun. The United Launch Alliance Delta-IV Heavy rocket successfully released the probe just under an hour after launch. If successful, it will be the first time that a spacecraft has ever been sent into the atmosphere of the Sun. Learn all about the mission on page 68.

TECHNOLOGY

AI for eye diseases

Moorfields Eye Hospital in London, Google's DeepMind and UCL have found that artificial intelligence performs just as well as human experts when detecting eye conditions from complex scans. The algorithm did not miss a single case that would require an urgent referral.

ENVIRONMENT

Chimps reveal human diet clues

Chimpanzees are ripe fruit specialists but also eat leaves and seed pods. New research has shown that chimps in the African savannah are chewing tougher food than their tropical rainforest counterparts, and it's believed our hominin ancestors also ate harder foods.

The mini-moons may help researchers learn about the composition of asteroids, like 243 Ida (pictured)

SPACE

New telescope could locate mini-moons

The Large Synoptic Survey Telescope may find these elusive rocks orbiting Earth

Mini-moons are thought to be between one and two metres in size, and while scientists are pretty sure there are a lot of them orbiting our planet, only one has ever been confirmed. A new telescope, the Large Synoptic Survey Telescope, is currently under construction and it is hoped that it may be able to detect more of these rocks by tracking their orbits. The mini-moons are predicted to fly-by the Earth, or sometimes make a revolution around the planet, before eventually escaping orbit or entering our atmosphere.

TRANSPORT

Cold weather could slow EV recharging

Lower temperatures may be impacting the electrochemical reactions within the batteries of electric vehicles

The onboard battery management systems of electric vehicles (EV) are thought to limit the charging rate to prevent damage due to cold weather interfering with the reactions inside the cell. A study by Idaho National Laboratory on a fleet of electric taxis in New York looked at data from charging Nissan Leafs between -10 to +40 degrees Celsius. The research revealed that when an EV battery was charged using a direct current charger for 30 minutes at 25 degrees Celsius, this would charge it to near 80 per cent capacity. However, at 0 degrees Celsius the battery's charge was 36 per cent less after the same amount of time.

Electric vehicle drivers may need to charge their vehicles for longer during cold weather

SPACE

Spacewalk live

NASA airs Russian cosmonauts strutting their stuff on a spacewalk

Broadcast live from NASA Television and streamed online, viewers watched Expedition 56 flight engineers Oleg Artemyev and Sergey Prokopyev of the Russian space agency, Roscosmos, leave the airlock of the International Space Station and venture out into space. Their mission was to complete maintenance and research tasks. Along with launching four small technology satellites, the pair retrieved material science samples from the hull of the Zvezda service module. The Zvezda module was the first entirely Russian contribution to the ISS and served as one of the early human living quarters. The rest of their time was spent installing an experiment called Icarus onto the Russian segment of the ISS. Icarus is intended to study the migratory patterns of small animals on Earth, part of a collaboration between the German Aerospace Center (DLR) and Roscosmos. The installation included fitting an antenna and GPS hardware for tracking tagged animals. The data from Icarus will monitor how and where animals migrate, their population density shifts and the spread of disease. The spacewalk was completed in seven hours and 46 minutes.

Cosmonauts Sergey Prokopyev (blue-striped suit) and Oleg Artemyev (red-striped suit) pictured here laying cable for the Icarus experiment

SCIENCE

Gene therapy can help cure blind mice

Scientists have partially restored rodents' vision by reprogramming retina cells

Researchers have used gene transfer therapy to turn Müller glia (non-neuronal cells in the retina) into rod photoreceptor cells (which detect light) in mice with congenital blindness. The therapy was inspired by regenerative processes that occur in cold-blooded vertebrates like zebrafish. When these animals' retinas are injured, the Müller glial cells copy and reprogramme themselves to replace the damaged photoreceptors. Mammals have lost this useful ability, but innovative cell reprogramming therapies can mimic it.

The procedure involved two injections of specific proteins into the mice's retinas, one to force the glia to re-enter the cell cycle and another to encourage them to turn into rod cells. This partially restored some vision in the mice.

It is hoped that the techniques from this study could someday help treat some forms of sight loss in humans

ENVIRONMENT

‘Biological passport’ reveals whale shark habits

A new method to monitor the endangered whale shark reveals they aren’t as mobile as we had thought

Researchers at the University of Southampton have used a ‘biological passport’ to track whale shark movements across the oceans. The techniques use small samples of the whales’ skin tissue and measure the isotopes levels of nitrogen and carbon to identify their feeding and movement behaviours. By using this information alongside the whales’ unique skin spots, an individual biological passport can be created. Over the course of ten years researchers have found that, out of 1,240 individuals, only two had travelled the 2,000 kilometres between the study sites in Mozambique and Tanzania.

Whale sharks can grow up to 12m long and weigh as much as 22,700kg

ENVIRONMENT

Microorganisms are tunnelling through crystals

Garnet crystals from Thailand have revealed tiny tunnels made by microorganisms. Chemical analysis of the tunnels revealed filament-like structures implicative of bacteria or fungi, suggesting a microbe dwelling. Though damaging to the value of the crystal, the discovery reveals a previously unrecognised habitat for rock-dwelling organisms.

TECHNOLOGY

Boeing invests in metal 3D printing

Several investors, including Boeing’s HorizonX Ventures, have together put a total of $12.9 million (£10.2 million) into Digital Alloys Inc., a company developing high-speed, multi-metal manufacturing systems called Joule Printing™ to produce 3D-printed aerospace parts.

TRANSPORT

Over half of drivers don’t look for cyclists

Using a wearable eye-tracking technology, researchers have found that when making turns, 11 out of 19 drivers failed to check areas of importance for spotting cyclists before turning.

INTERVIEW

Beetlemania with M G Leonard

We speak to the author of the *Beetle Boy* series about her fascination with these often-overlooked insects

Was there a particular moment in your life that sparked your interest in beetles? What is it about them that captured your attention?

The moment I discovered that I didn't know what a beetle was, was the moment my interest in beetles exploded. I had thought I knew, but then I came across their scientific name – Coleoptera. 'Coleoptera' was not a word I had encountered before, so I looked it up. It translates from Ancient Greek as 'sheath wing'. The primary distinctive feature of all beetles is that they have two pairs of wings – a hard outer pair and then sheathed beneath that is a soft, membranous pair of wings, and most of them can fly. I was shocked. When I closed my eyes and pictured a beetle, it was a small, black crawling creature – which I now know to be the common ground beetle. I did not know that beetles had wings or could fly. I had thought I was well educated and reasonably knowledgeable, but I obviously wasn't if I didn't even know what a beetle was. This realisation came as I stared at a webpage full of amazing facts about how important the humble beetle is to the planet, how there are over 400,000 species that live in every conceivable habitat on Earth (with the exception of the Arctic and salt sea water). How was it possible that I didn't even know what a beetle was when one in every four living things on this planet is a beetle? I went out with friends that evening and I asked them to imagine a beetle and describe what they saw. Not one of them imagined wings. When I told them what I'd discovered, I was surprised to realise that none of them knew what a beetle was either. I realised someone needed to write about these amazing, overlooked creatures. It turns out that someone had to be me.

The *Beetle Collector's Handbook* is a great way of getting younger readers interested in beetles. When did you get the idea to create a non-fiction accompaniment to your *Beetle Boy* trilogy?

The idea for the handbook came while I was writing *Beetle Boy*. I wanted Darkus, my protagonist, to know nothing about beetles at the beginning of the adventure, just like the reader, and his growing knowledge had to come from somewhere. Where better than a book? I looked for comprehensive beetle books and couldn't find one in print. Eventually, I found a book printed in the 1900s called *The Beetle Collector's Handbook* and decided to base the book in the story on that book. The original book has long been out of print. The language is old-fashioned, as are some of the attitudes towards the natural world, making it hard to understand, and it lacks humour. I thought, if *Beetle Boy* does well, I would like to write a contemporary version of this type of book for children today.

How did you go about researching the book? Did you discover any particular facts or new beetle species you were unaware of?

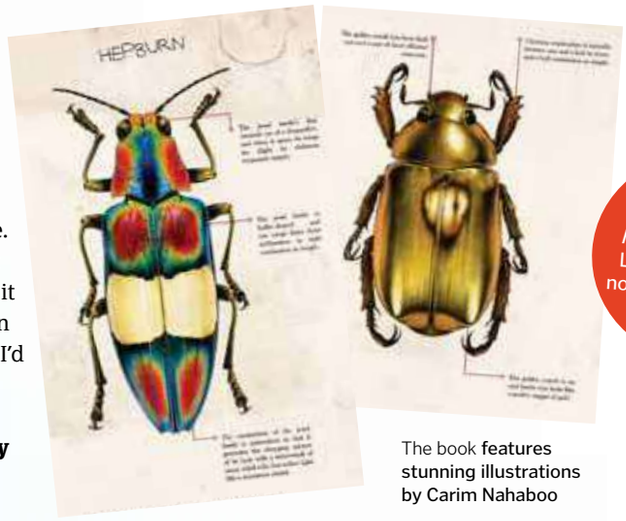
I started with the six years of research I had done for my fiction books. I wanted to make sure that the beetle characters in my stories featured in the non-fiction. I have interviewed many entomologists over the years and knew that I wanted the book to have a narrator, a fictional entomologist, sharing their beetle knowledge, rather than a blitz of facts. I also wanted the book to make what can seem to be a complex and baffling science relatable, easy to understand and fascinating. After establishing a list of the most interesting beetles, I began researching each one. Entomology is a complex science because knowledge isn't fixed but rather evolves with our understanding of the world of mini-beasts, and new species are discovered all the time. I am always discovering new facts and species, as are the scientists working in the field. I could spend my whole life learning about beetles and still be continually surprised. Humans may have discovered and described 400,000 species of beetle, but it is believed there are another 2 million species we are unaware of.

If you had to pick your favourite beetles, which would they be and why?

Choosing a favourite beetle is tough because there are so many cool ones. I think the rhinoceros beetle has character, which is why I made him the hero beetle of my trilogy. They are impressive-looking creatures, the size of small birds, but they have superhero strength. Did you know a rhinoceros beetle can lift 100 times its own body weight? That would be like me being able to lift an elephant! I also love the bombardier beetle as it shoots boiling acid out of

> "Someone needed to write about these creatures. Turns out that someone was me"

its bottom at predators. The tiger beetle is pretty special too. It is emerald green with spindly legs and runs so fast that it can't see. It has to sprint in short bursts and has giant bulbous eyes to orientate it when it stops. If it were the same size as Usain Bolt it could run the 100 metres in 0.9 seconds! That is a race I'd love to see.



The book **features stunning illustrations by Carim Nahaboo**

The Beetle Collector's Handbook by M G Leonard is on sale now from Scholastic **RRP £10.99**

Is there a particular species you'd really like to see? Perhaps something rare or exotic that not many people have the chance to observe?

The biggest beetle on the planet is the *Titanus giganteus*. It is the size of a rat. They are now an endangered species because of habitat destruction and climate change. No human has ever seen the larva of a titan beetle, because they live and grow inside the trunks of trees. From the holes they make as they bore their way through the tree, eating and growing, it is estimated the larvae grow to about 30 centimetres in length and five centimetres in diameter. I would love to see one, and also witness the flight of such a large beetle. It must be a wondrous spectacle.

Beetles are often overlooked when people think about their favourite animals. How do you hope *The Beetle Collector's Handbook* could improve people's appreciation for these creatures?

We should know more about the heroic mini-beasts that do many important jobs in our ecosystem. Once you begin discovering the wonder of beetles it's hard to stop. I'm hoping *The Beetle Collector's Handbook* will be an entertaining and delightful introduction to some of the coolest and freakiest beetles out there, but it is only a beginning, the first footsteps on a path to a better relationship with the creatures in our gardens and parks.

How could readers go about observing beetles in their gardens or parks? Where are the best places to look?

You can look for beetles anywhere. There are a host of tiny beetles that live in our houses. However, the most fun can be had with a sweeping net (a hardy butterfly net) and an overgrown patch of land. If a garden is over manicured and controlled with pesticides then you'll find no insects. What you want is a wildflower meadow, or a woodland with piles of rooting wood, or a footpath with hedgerows, weeds and a mix of plants. If you have a garden with a pond you'll discover a wonderful range of insects thriving around it. You may even have water beetles. I always pack little pots with magnifying lids and air holes, to look closely at the beetles I catch, before setting them free. You will have to get down on all fours and have a good rummage for some of the ground beetles, but it is impossible not to find something.

Do you have any tips for readers interested in keeping beetles as pets?

I have kept pet beetles for three years. Right now in my beetle zoo I have a pair of black chunky Dorcus stags, a pair of pretty pink Indonesian stags, a pair of stunning Australian rainbow stags, three yellow-and-black sun beetles and five African flower beetle larvae. They are the easiest pets to keep. Their tanks need regular misting to make sure they don't dry out, and the adults eat little pots of jelly, but you can leave them for days and they're fine. I keep them in my study and find them excellent companions while writing. I have a page on my website with links to beetle suppliers and videos about how to look after beetles, but it is really quite simple as long as you remember that they fly.

Beetles can make great pets and are easy to keep – just make sure you read up on how to care for them first

WISH LIST

The latest must-have technology

Moov Now

■ Price: **$59.95 (approx. £50) / welcome.moov.cc**

There are many fitness trackers currently on the market. However, Moov Now offers the wearer more than just the necessary workout information – it includes a built-in personal trainer. Connected wirelessly with the accompanying app, Moov can now support a range of exercises including running, swimming, cycling and general workouts. What's unique about this fitness tracker is the level of detail in its AI-assisted exercise analytics. From arm strokes while swimming to the force at which your feet are hitting the ground while running, the built-in trainer will advise on your form to help you get the most out of your workout. Within the accompanying app there are pre-programmed indoor exercises for which the Moov Now can track your performance and progress and give you feedback in real time. It's ultralight at only 15.1 grams and boasts an impressive battery life of up to six months.

GEOSMART Moon Lander

■ Price: **£39.99 / $52.99 / geosmart.eu**

Combining the novelty of building blocks with the electronics of a remote control rover, GEOSMART has created the Moon Lander. As a build-it-yourself product, the Moon Lander is made up of 31 vibrant geometric shapes that house magnetic strips for easy construction. To make the Moon Lander move, simply click together all the components (including snap-in motors and tracks) and drive it with the wireless remote. Due to its DIY design, users can create a Moon Lander in whatever shape and style they want. The kit is simple to use, making the Moon Lander the perfect gift for any child over the age of five. Not only is it fun for all the family to play with, but the Moon Lander is also an excellent tool to teach children about the geometric shapes, construction and basic electronics while allowing them to express their creativity.

Moodo fragrance diffuser

■ Price: **From €174.22 (approx. £155 / $200) / moodo.co**

Smarthome appliances continue to grow and diversify, and with the introduction of Moodo, the way we fragrance our homes can now be made smart. Moodo is a wi-fi-connected fragrance diffuser you can control from your phone just like any other smart home device. Replacing wall plug-in air fresheners and aerosol cans, it uses four scent capsules to create a unique aroma. All Moodo fragrances are created from the finest natural sources and include scents such as Spice Bouquet and Sea Breeze. By using the turntable DJ style app, fragrances can also be mixed for personal preference.

LittleBits Droid Inventor Kit

■ Price: **£99.99 / $99.95 / littlebits.com**

As always, our favourites on the Wish List are the things that are both educational and really fun, so we love this kit that uses electronic blocks and a Droid Inventor app to teach an R2 Unit new tricks and guide it through more than 16 different missions. You can get creative and technical as soon as you take the R2 out of the box – and you can start building and programming straight away because it already comes with the stickers, batteries and extra accessories needed to get going.

Feel Flux

■ Price: **From $49 (approx. £40) / feelflux.com**

The gravity-defying Feel Flux is mesmerising; using a magnetic tube and superstrong neodymium magnet ball to create a levitating physics toy. They work due to Lenz's Law, which describes how the falling ball creates a change in the magnetic field inside the metal walls of the tube that induces voltage. This voltage creates electric currents that flow around the tube, which generate another magnetic field that opposes the motion generated by the falling ball. So the faster the ball reaches the tube the stronger the opposing force becomes.

They're really satisfying to use as a desk toy to fiddle with, but you can also learn tricks if you use the Feel Flux Skill Set. It takes some practise but is really impressive once you get the hang of it!

Tractive GPS

■ Price: **£44.99 / $74.99 / tractive.com**

This piece of pet tech is great to keep your cat or dog safe. The Tractive comes in the form of a full collar (for cats) or a collar attachment (for dogs) and offers users live tracking – updated every two to three seconds – to give you peace of mind as to their whereabouts. Whether you're concerned your dog might wander off during a walk, or you just want to check up on them while you're at work, the Tractive makes keeping tabs on your pets as easy as checking your phone. The GSM, GPS and Bluetooth technology mean you can locate your pet reliably even if you're on the other side of the world. We particularly like the feature that allows you to define a safe area that your dog or cat can explore, such as the garden or your local neighbourhood, with the app alerting you immediately if your furry friend leaves that space.

APPS & GAMES

Flight Pilot Simulator 3D

■ Developer: **Fun Games For Free**

■ Price: **Free / App Store / Google Play**

This flight simulator game takes players to new heights with its excellent 3D graphics. Players can fly passenger jets, military aircraft and more through a variety of different scenarios.

TerraGenesis – Space Colony

■ Developer: **Tilting Point**

■ Price: **Free / App Store / Google Play**

If you enjoy civilisation creation games, then TerraGenesis takes the challenge to the next level. Based on NASA exoplanet data, in this simulator players can try their hand at establishing life on other worlds throughout the Solar System.

Brian Cox Wonders Compilation

■ Developer: **HarperCollins Publishers Ltd**

■ Price: **£1.19 (approx. $2) / Google Play**

Join Professor Brian Cox on a journey through the universe, from the smallest particles to the planets of our Solar System and beyond to distant galaxies.

BrainPOP Featured Movie

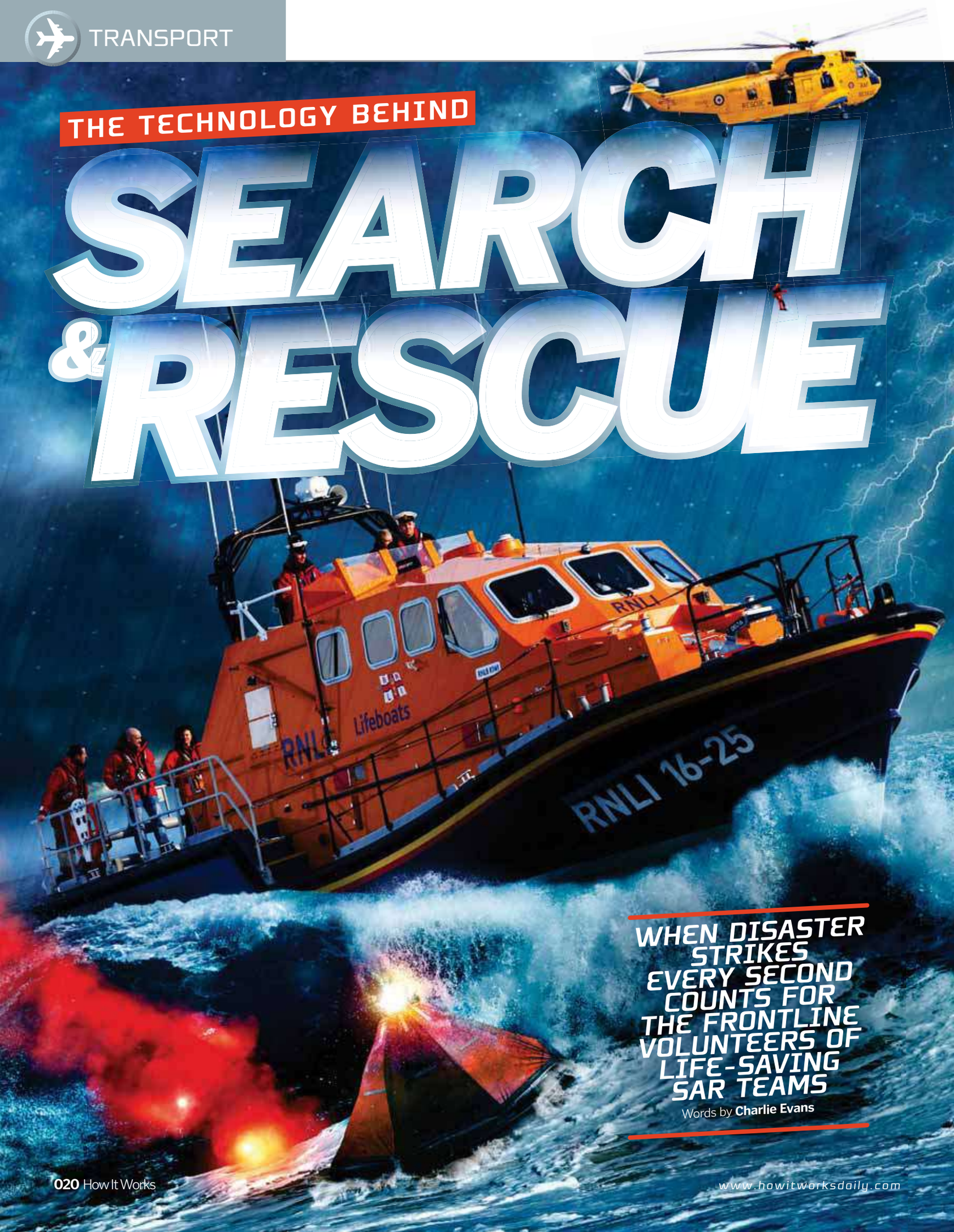
■ Developer: **BrainPOP**

■ Price: **Free / App Store / Google Play**

This app provides entertaining and informative videos and quizzes covering loads of science, technology and engineering topics.

THE TECHNOLOGY BEHIND

SEARCH & RESCUE



WHEN DISASTER STRIKES EVERY SECOND COUNTS FOR THE FRONTLINE VOLUNTEERS OF LIFE-SAVING SAR TEAMS

Words by **Charlie Evans**

Huddled inside a cave, a young football team shivers with their knees tucked into their chins and shirts pulled over their legs. The boys and their coach have been trapped for ten days after an expedition into Thailand's Tham Luang cave quickly turned from celebration to disaster.

When monsoon rains hit and the water levels rose, they desperately sought higher ground, squeezing through narrow tunnels and passageways as they were forced further into the cave system. They could find no escape, but about three kilometres from the cave's entrance they found a small rock ledge high enough to keep them safe. In total darkness, they clambered onto the ledge and hoped for rescue. Without food, and with oxygen levels running low, their chances of survival were slim.

There was little hope that the boys were still alive when their bikes were found outside the cave, but the rescuers were determined; in a matter of hours soldiers, doctors and divers assembled among the tents of families and volunteers. Water pumps were carried to the site to try and lower the water levels in the cave. As the boys sat trapped by the water, they had no way of knowing that outside more than 1,000 people from around the world had rallied to their aid, or that the events about to unfold would become one of the greatest rescue missions in recent years.

After dozens of divers scoured the cave, help finally arrived for the boys. A torch pierced the darkness of their chamber, and a British diver emerged from the water shouting: "We are coming. We are the first. You have been here ten days. You are very strong." Sadly, during a dive to take oxygen to the boys, Saman Kunan, a former Thai Navy SEAL, lost his life. This tragedy highlighted the dangers involved in the rescue efforts, even for the most experienced divers. Over the next few days divers took the boys food, water and medical supplies as the world watched on as each one was sedated and removed, held by rescuers who navigated the frozen water and jagged rocks. Then, more than 17 days after they first entered the cave, all 12 boys and their coach emerged alive and into the arms of their families and friends.

The rescue effort captured the world's attention, but it isn't the only one of its kind. Every day, it's estimated that over 600 people go missing globally due to crime, natural disasters or tragedy at sea and on land. This can occur anywhere, from the open ocean to the shoreline, from mountains and forests to caves and countryside. Being part of the teams that search for and rescue people in danger is a job that takes determination, bravery and skill, and it relies on a combination of advanced technology and intense training.

Search and rescue (SAR) teams worldwide work tirelessly to safely return missing people home from being lost on the land or at sea. In the UK, the largest SAR organisations consist mainly of volunteers, including the Bristow Group's Helicopter Service, Lowland Rescue and UK SAR. Yet these are just some of the many SAR teams that race against the clock to find those in critical danger and battle some of the world's harshest weather and toughest terrain to save lives – no matter when or where.

A grid search team will inspect smaller areas thoroughly and often find clues to further guide the search

Robots to the rescue

Joining the search for missing people – and pushing the boundaries of search and rescue technology – are squadrons of rescue drones. These 'eyes in the skies' are able to analyse the situation in the aftermath of natural disasters, as well as assist in locating casualties and exploring dangerous locations such as collapsed buildings and chemical spill sites.

When it comes to tackling terrain too tough for humans, these robots are relatively recent additions to the SAR toolkit, but they are aiding rescue missions by providing full HD and thermal imaging technologies. Martin Kingman, a drone pilot with Kent Search and Rescue (KSAR), explains.

"They enable us to gain up-to-date topography of how the land lies, which can be relayed back to our control vehicle by live down-link," he tells How It Works while expertly manoeuvring the drone over a fleet of rescue vehicles. "Drones can search areas where access is difficult or putting teams on the ground would endanger the teams – such as the mudflats on the banks of the River Medway. They can also be used to collate evidence without contaminating the scene in the unusual event of a crime being committed."

KSAR's DJI's Mavic drones can cover a range of over 10km, providing high-resolution real-time video

"These are the teams that race against the clock to find those in critical danger and battle some of the world's toughest terrain to save lives"

MOUNTAIN & LOWLAND RESCUE

The search and rescue teams on the ground – tackling rivers, rocks and ravines – form the backbone of the land emergency response

A broken ankle and no phone signal can quickly turn a gentle hill walk into a deadly trek; as the night draws closer and the temperature drops, the ground search and rescue teams are responsible for finding those who have gone missing on land.

Whether you're scrabbling through a cave or traversing a field, you can't carry a giant case with you equipped with everything you need, and the further off the beaten track you stray the harder it becomes to carry equipment. The work for land rescue is much more about relying on your senses and keeping equipment light, so these SAR teams are highly trained to use their observation and intuition and will usually find clues that will direct other searchers as they scour the area.

SEARCH ON FOOT

Searching on foot is almost always the first plan when a person is reported missing. After gaining some information about the missing person, such as their last known location and what clothes they were wearing, a map is divided into search areas before the teams organise themselves. Grid searching is what comes to mind when you think of the hunt for a missing person; a long line of volunteers walking across open fields examining the ground. A trained grid search team can cover approximately 1.6 kilometres in 3.5 hours by walking slowly and deliberately and taking time to survey each bush and debris encountered for vital clues.

The other main type of searching, known as hasty searching, is almost the opposite. As the name suggests, hasty searchers work so fast they are almost jogging, and they explore vast areas and check the most obvious places where a missing person may have been wounded or stopped to rest, such as cliffs, ditches and caves. The teams at UK SAR are trained to identify tracking signs including broken branches and footprints, but when the terrain gets more difficult they can use equipment such as bikes, kayaks and boats to continue their search.

Engines
The Sikorsky S-92 can fly at speeds of over 145 knots (around 270kph) thanks to its twin GE CT7-8A turboshaft engines.

Spacious cabin
The large cabin contains 19 crash-safe seats with large windows at every row, which can be pushed out to create an emergency exit.

Fuel safety features
The sponson is designed to maximise the distance between fuel and passengers, and a suction fuel system prevents fuel spray.

Winch
The winch can be fitted to hoists, harnesses and stretchers to help raise and lower rescuers, victims and equipment to and from the helicopter.

"A trained grid search team can cover around 1.6 kilometres in 3.5 hours as they search the area for vital clues"

COMMUNICATION TECHNOLOGY

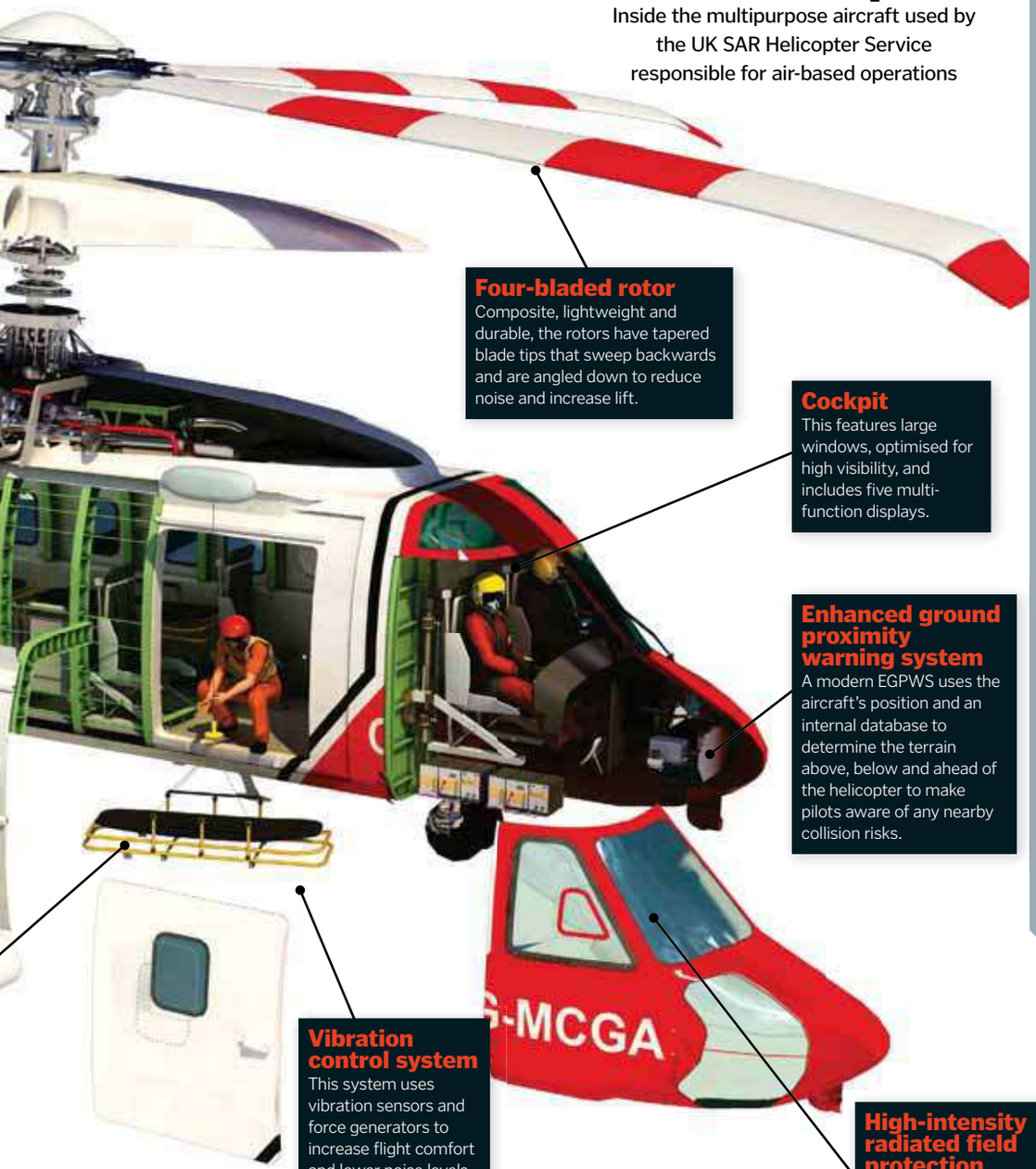
There is some equipment that will always come with a search team, despite the difficulties carrying it on a search. Gary Mitchell, surface support in the Tham Luang cave rescue, spoke to **How It Works** about the technology they used.

"In any rescue we need to know exactly what is happening underground and where people are and in what direction people are moving, and 'heyphones' were one of our staple pieces of equipment."

Heyphones are commonly used by cave rescue teams, in addition to the more standard VHF radio used by ground rescue, as the low frequency is able to penetrate through rock and deep into the ground using induction loop antennas or electrodes in the ground. Communications become even more important when the missing person is found but isn't in good health. "You need instant comms so you can know the condition of the casualty – if they're getting better or if they're deteriorating."

The Sikorsky S-92 helicopter

Inside the multipurpose aircraft used by the UK SAR Helicopter Service responsible for air-based operations



Four-bladed rotor
Composite, lightweight and durable, the rotors have tapered blade tips that sweep backwards and are angled down to reduce noise and increase lift.

Cockpit
This features large windows, optimised for high visibility, and includes five multi-function displays.

Enhanced ground proximity warning system
A modern EGPWS uses the aircraft's position and an internal database to determine the terrain above, below and ahead of the helicopter to make pilots aware of any nearby collision risks.

Vibration control system
This system uses vibration sensors and force generators to increase flight comfort and lower noise levels by minimising the shaking of the aircraft.

High-intensity radiated field protection
HIRF in the helicopter protects passengers, crew and the electrical systems from harmful frequencies encountered at altitude.

A helping paw

There is no technology more sensitive than the nose of man's best friend, and SAR dogs are one of the most valuable assets to a team locating a missing person. Our canine friends are particularly adept at covering vast distances in the wilderness and climbing over the rubble of collapsed buildings to track the scent of a person.

Training starts when they are puppies once they learn to air scent – a natural skill to dogs as they can pick up the smell of the 40,000 skin cells a human sheds every minute. Jo Kenny, one of the SAR volunteers in Kent, explains. "They're trained exactly the same as mountain rescue dogs. We face the dog's nose into the wind, so if there is a human somewhere, they can locate it." The dogs are trained using treats when they successfully find a person and always work as a duo with their handler.

Brock has almost finished his intense two-year training to become a search and rescue dog

The Airbus Super Puma SAR is often relied on in Iceland, where conditions make on-foot searches difficult

Rescuers in Alaska protect a victim from the downwash of a landing helicopter

Mountain climbers are particularly at risk of needing SAR assistance as injuries are common and they are usually unable to phone for help

MARITIME RESCUE

Catastrophe at sea brings a whole new set of challenges to SAR teams

Training drills in the ocean are essential for crew so they can respond efficiently when there is a real casualty

The ocean is unpredictable even for the most seasoned sailors; with few navigational landmarks, limited communication with the mainland, and erratic weather changes, it's easy for seafarers to find themselves in danger. Fortunately, experienced maritime teams are ready to come to the rescue. The training is intense, but with thousands of people going missing at sea every year, it is a vital service.

The Royal National Lifeboat Institution (RNLI) is a UK charity organisation dedicated to saving lives at sea. Their 24-hour lifeboat search and rescue service has saved over 140,000 people since its foundation in 1824 and prides itself on the courage of its volunteers, who work tirelessly to keep people safe and return them to dry land. Whether it is rescuing the passengers of sinking ships, pulling yachts with engine failure back to shore, or searching for people dragged out into the ocean due to strong currents, the RNLI average 24 call-outs every day.

The volunteer teams around the UK are provided with state-of-the-art equipment and first-class training, during which they learn sea safety and survival techniques and how to operate radar, electronic navigation equipment and rescue boats. The RNLI College in Poole is home to a unique wave tank that simulates violent weather. The special effects are incredibly realistic. A powerful wind machine creates gales, while sound and lighting systems recreate thunderclaps and lightning. This means the teams can practise capsizing drills and sea survival, so when they first experience an emergency they will deal with it confidently.

According to Andy Buck, an RNLI volunteer, the biggest problem in a search and rescue can be identifying someone's location. "It can be difficult because there are no landmarks at sea – it's just water, so people don't always know where they are located. But we can triangulate positions of a distress call while we're on the boat when someone calls on the radio."

When emergencies are closer to the shoreline it falls to Her Majesty's Coastguard – a branch of the Maritime and Coastguard Agency – to take action. The two organisations work together closely to ensure the safety of those in UK waters.

The Shannon Class lifeboat

The first all-weather waterjet-propelled lifeboat to join the RNLI fleet has started to replace the service's older vessels

Navigational systems
The new lifeboats have the latest technology installed, including GPS and radar, so the crew can navigate at sea.

Self-righting
A clever new design allows the boat to right itself if it capsizes.

Streamlined shape
The Shannon Class has a narrow bow to allow the boat to cut through the water, which is counteracted by wide aft sections to keep it steady and upright.

Twin jets
Twin waterjets offer power and great manoeuvrability in addition to allowing the lifeboat to operate in shallow water where propeller-powered vessels would struggle.

Engine
A mechanic stays onboard for the duration of a call-out, in case any engine maintenance or repairs are required.

The new Shannon Class RNLI lifeboats are faster and better equipped than the older models they are replacing

Interview with an RNLI volunteer

Andy Buck, a volunteer based at RNLI Margate, spoke to **HIW** during one of the charity's busiest weeks of the year

You seem to be really busy the last few days. What's been happening?
It's the first week of the summer holidays. A lot of people think lifeboats are busy in bad weather but generally it's not the case – most of our shouts are in the summer to pleasure craft and people bathing. We average about 50 to 60 launches a year and two-thirds of those are in the warmer months.

What are your most typical rescue jobs?
Dinghies, people cut off by the sea. They've walked around and realised they can't get any further because of the tide. There were 55 people caught like that the other day. We get boats broken from moorings, sailors reporting debris in the water that could be a boat – there could be someone onboard that's fallen in, so we have a duty to investigate.

Have you had any recent search and rescues incidents?
We had one, a motorboat with engine failure. It was his permanent home, and he got in distress. We had to tow him back, with his pet dog and his seasick cat – his very seasick cat.

Systems and Information Management System
This network of computers and screens enables crews to monitor, control and operate the boat's key systems.

Anchor
A heavy anchor allows the boat to stop and stay secure while conducting a rescue.

Head to howitworksdaily.com to read the interviews in full

Composite hull
The lifeboat's fibre-reinforced hull protects against violent waves and any incoming debris.

"With courage, nothing is impossible"
Sir William Hillary (1771-1847)
Founder of the RNLI

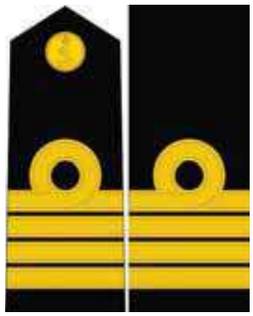
Royal Navy ranks

Britain's ships ruled the waves for centuries and were manned by a rigid hierarchy of officers and sailors that is still used today

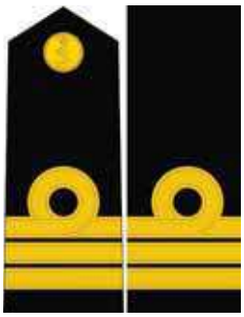
Admiral
Commanding a squadron of up to 30 ships, admirals are responsible for carrying out orders from the head of the navy (admiral of the fleet, or first sea lord) and co-ordinating operations across all vessels in their charge.

Vice & rear admiral
Second- and third-in-command respectively, the two lower-ranked admirals deputise for the admiral in their absence. The vice commands the vanguard and the rear admiral commands the less important vessels.

Commodore
The senior-most captains in service can receive this entry-level of the 'flag ranks'. They will take on much of the responsibilities of a rear admiral, commanding a small squadron of vessels.

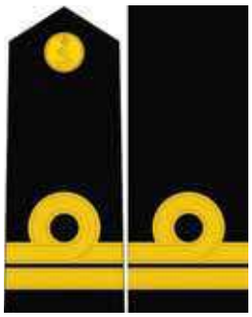


Captain
The highest-ranking officer of a vessel is ultimately responsible for their ship and its crew. They also ensure orders are carried out and keep a meticulous record of all the ship's activities.



Commander
Originally created for officers commissioned for smaller vessels, on larger ships this role acts as second-in-command to the captain and can take charge in their absence or incapacity.

Lieutenant commander
After eight years' service, lieutenants can attain this more senior rank, earning greater responsibility over the ship's operations. This rank can also be commissioned to command a small vessel.



Lieutenant
Pronounced 'lef-tenant' in the Royal Navy, this rank was traditionally the lowest commissioned officer post. Lieutenants are responsible for overseeing the crew's tasks and maintaining discipline.

Midshipman
Historically, midshipmen were boys from wealthy backgrounds seeking a prestigious career in the service. They would undertake extensive training at sea before taking the lieutenant's exam.

Warrant officer (1 & 2)
Doctors, engineers, masters-at-arms, gunners, cooks, electricians and many other practical roles all fall under the 'Special Duties List' officers, which traditionally had its own separate career progression.

Petty officer
Ordinary ratings gaining promotion could eventually hold a similar position to sergeants in the Army, supervising day-to-day operations aboard ship, while also maintaining standards and discipline.

Able rate
Almost any task, from keeping watch to cleaning equipment or operating weaponry, could be assigned to a rating, or able sailor. In the past, ratings would also clamber up the tall rigging of the ship.

Prince Philip, Duke of Edinburgh, pictured in 1947 when he was a lieutenant in the Royal Navy

AIRFIX

QUICK BUILD

J6015
Blue Beetle

J6023
Yellow Beetle

4	m 4.07	m 1.5
m 1.54	kg 725	km/h 115
L/100km 7.5	0-100km/h 23s	kW 40
1.2L Flat 4		

A Model for the People – VW's Most Iconic Car

TThe Volkswagen Beetle, or it's official title the Volkswagen Type 1, was the first car to be produced by the company we all know today as Volkswagen. The Beetle has a very interesting history of how it came to be that you may not expect of this iconic car.

The idea was formulated by Nazi leader, Adolf Hitler, who wanted a simple, mass-produced, cheap car to be manufactured for his country's new road network. Chief engineer for the project, Ferdinand Porsche, finalised the design of the functional "People's Car" in 1938. The result was a rear-engined air-cooled saloon which was rugged, simple and reliable in any sort of extreme weather conditions.

The name has also stuck around ever since as "Volkswagen" literally translates from German as "people's car."

The Volkswagen Beetle entered the record books as the bestselling single-model car of all time on February 17th 1972 when production reached 15,007,034 units, beating the previous record of the Ford Model T. When production finally ceased on July 30th 2003, Volkswagen had produced a total 21,529,464 and it's unlikely this record will be broken again as cars now rarely remain in production longer than 10 years.

Although Volkswagen's legendary advertising campaign for the US market highlighted the fact that the Beetle did not change year-on-year, making it easier to source parts, it did develop over the years because of both market pressure and legislative changes. The first obvious visual change was in 1953 when the vision-limiting 'split' rear-window was replaced by a one-piece oval design, which lasted until August 1957 before being superseded by an even larger rear-window.

The VW Beetle has become a true icon on roads all over the world! You can create your very own at home with an Airfix QuickBuild kit. QuickBuild kits give you the ability to recreate a wide variety of iconic aircraft, tanks and cars into brilliant scale models. No paint or glue is required, the push together brick system results in a realistic, sculpted model that is compatible with other plastic brick brands.

- **Comes in two colours, J6015 Blue and J6023 Yellow**
- **Includes 36 plastic parts**
- **18cm long when assembled**
- **Sticker sheet included for authentic decoration**
- **Has smooth lines just like the real thing**
- **Compatible with other plastic brick brands!**

Collect them all! Check out the rest of the range online.

J6019 Lamborghini Aventador

J6022 Challenger tank

J6020 Bugatti Veyron

Airfix.com and all good retail stockists YouTube

HORNBY HOBBIES
Official Product

How a paver works

Advancements in engineering mean road laying is no longer a time-consuming and resource-draining part of construction

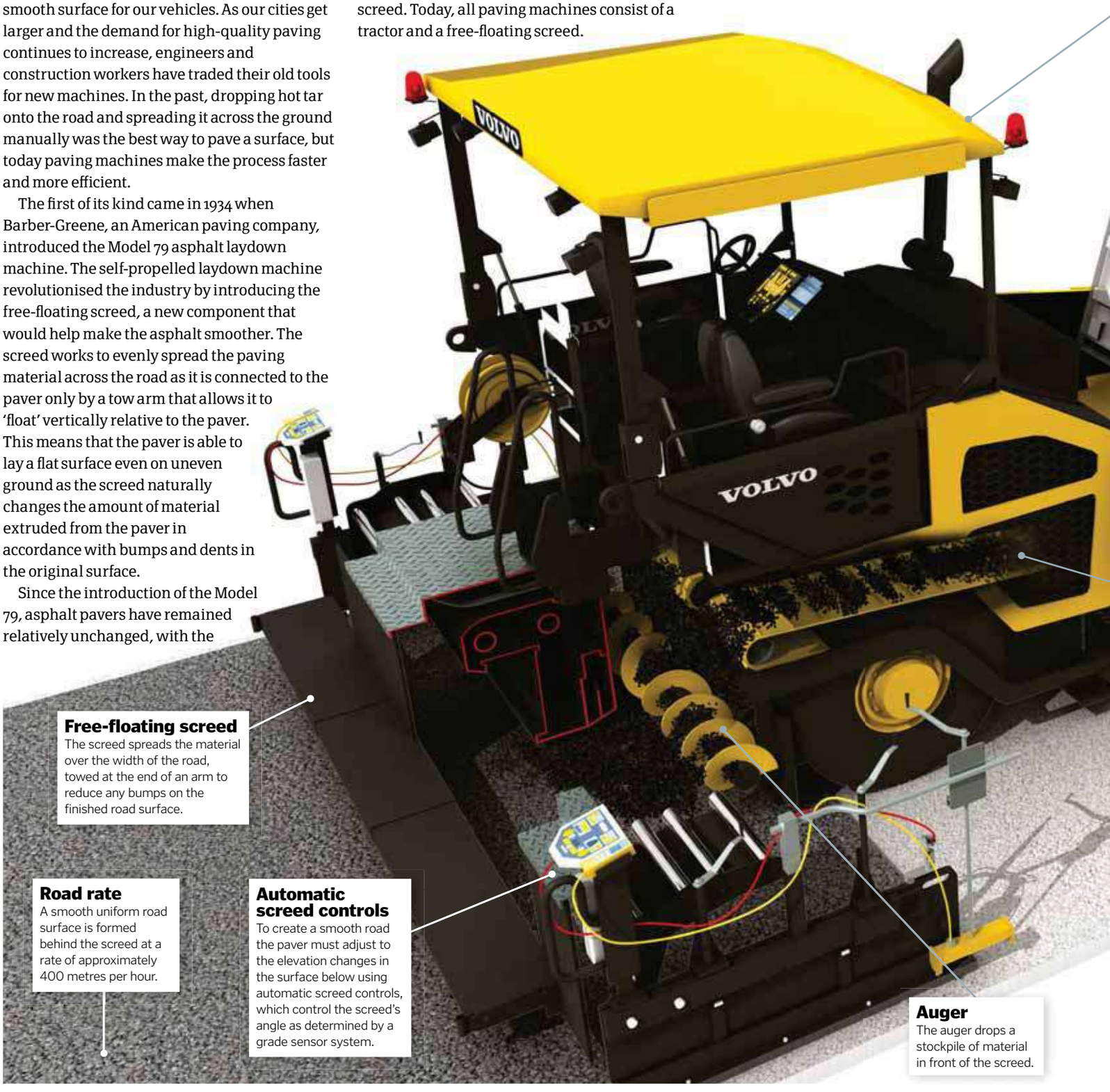
Roads, bridges, car parks – almost everywhere you look in urban areas you can see asphalt and tarmac providing a smooth surface for our vehicles. As our cities get larger and the demand for high-quality paving continues to increase, engineers and construction workers have traded their old tools for new machines. In the past, dropping hot tar onto the road and spreading it across the ground manually was the best way to pave a surface, but today paving machines make the process faster and more efficient.

The first of its kind came in 1934 when Barber-Greene, an American paving company, introduced the Model 79 asphalt laydown machine. The self-propelled laydown machine revolutionised the industry by introducing the free-floating screed, a new component that would help make the asphalt smoother. The screed works to evenly spread the paving material across the road as it is connected to the paver only by a tow arm that allows it to 'float' vertically relative to the paver. This means that the paver is able to lay a flat surface even on uneven ground as the screed naturally changes the amount of material extruded from the paver in accordance with bumps and dents in the original surface.

Since the introduction of the Model 79, asphalt pavers have remained relatively unchanged, with the paving material loaded into a hopper at the front and carried to the rear by conveyor belts before being spread out by augers and levelled with a screed. Today, all paving machines consist of a tractor and a free-floating screed.

Producing the perfect paving

Inside the machines that make our roads safe and smooth



Free-floating screed
The screed spreads the material over the width of the road, towed at the end of an arm to reduce any bumps on the finished road surface.

Road rate
A smooth uniform road surface is formed behind the screed at a rate of approximately 400 metres per hour.

Automatic screed controls
To create a smooth road the paver must adjust to the elevation changes in the surface below using automatic screed controls, which control the screed's angle as determined by a grade sensor system.

Auger
The auger drops a stockpile of material in front of the screed.

Slow and steady
The paver must move at a slow and steady pace to keep a consistent stockpile of material coming from under the screed at an even rate to ensure a smooth road surface.

Material transfer
The asphalt is added from a tipper truck into the hopper.

Heated body
The paver has an electrically heated body to keep the surfacing material liquid so it doesn't stick to the machine and can be laid more easily.

Conveyor belt
A conveyor belt carries the asphalt from the hopper to the auger.

Pavers have allowed for roads to be built faster to keep up with growing demand

5 FACTS ABOUT ROADS

1 History of the centreline
The first modern centreline was painted in 1917 after Edward Hines was inspired by a milk spill on a newly paved road.

2 Potholes are caused by water
Water penetrates the tiny cracks in the road and freezes during the colder months. Water expands as it freezes, so it causes the cracks to widen. When vehicles drive over these cracks, they form new potholes in the road.

3 Asphalt is the most popular paving material
In the US, around 94 per cent of the road network is surfaced with asphalt because it is cost-effective, long-lasting and sustainable.

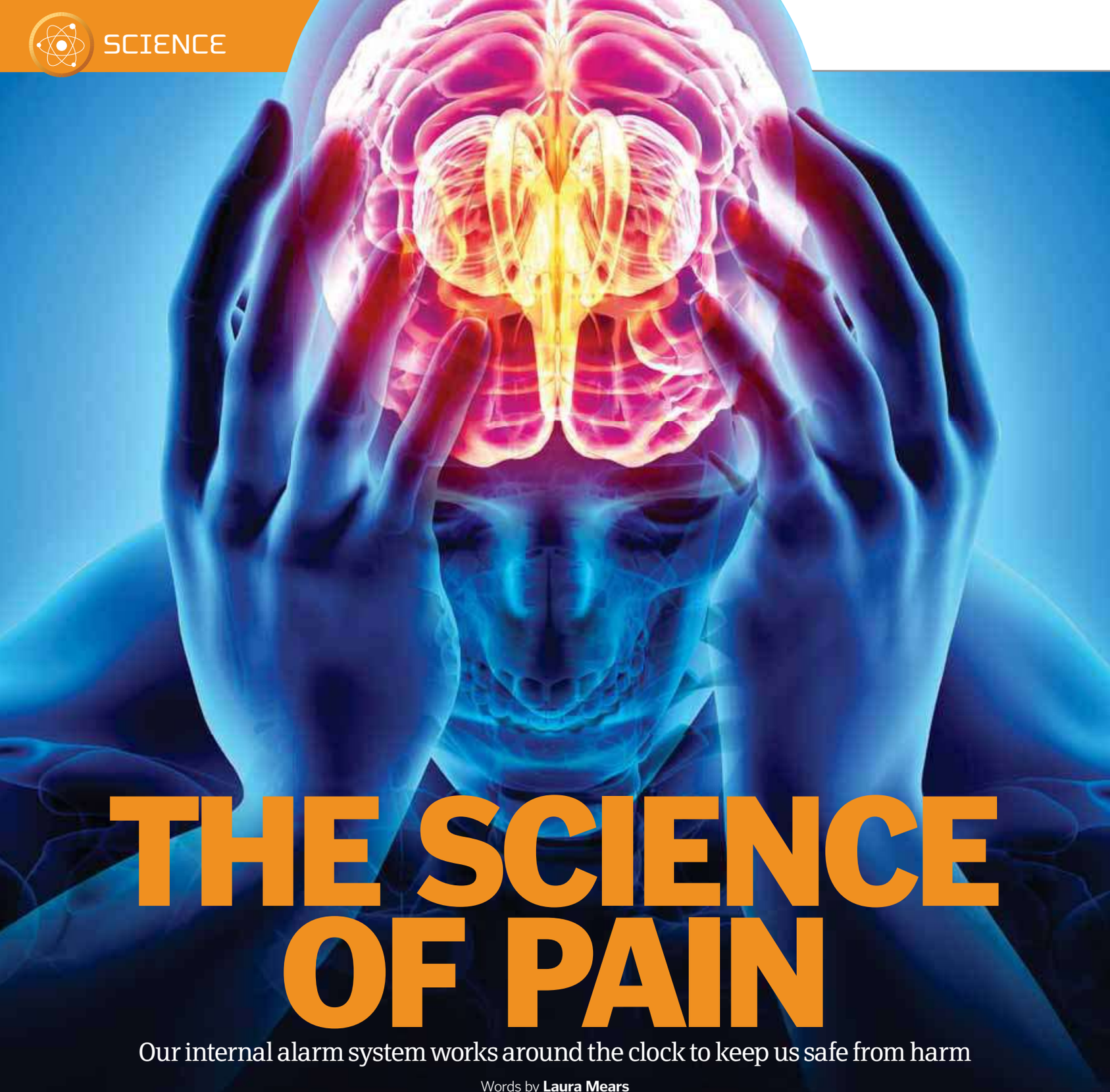
4 Smooth roads save fuel
Research in Sweden discovered that vehicles driving on the smoothest roads in the country consumed approximately ten per cent less fuel than vehicles on the roughest roads.

5 Asphalt can be recycled
When old asphalt has to be removed, around 80 per cent of it is recycled before then being re-used on new roads.

Road printing machines

You've heard of 3D printing, but have you heard of road printing? After piles of bricks are fed into the top, these machines arrange them and tessellate them together and 'print' the perfect road. They do this by harnessing the power of gravity, allowing each brick to fall into place. As the machine moves forward, a perfectly uniform brick road is formed and placed behind it, making brick laying almost as easy as laying down some laminate floor in a kitchen; it takes the heavy work out of what for years has been difficult manual labour. The Tiger Stone paver – developed in The Netherlands – is one machine able to do this and is wide enough to pave (or repave) an entire street in one go. This method saves time and money and is particularly useful in The Netherlands, where roads are replaced every seven to ten years due to the unstable upper layer of wet soil.

Road printers are the fastest and most reliable way to build a brick road



THE SCIENCE OF PAIN

Our internal alarm system works around the clock to keep us safe from harm

Words by **Laura Mears**

Millions of sensitive nerves guard our tissues, listening for physical danger. These pain sensors, or nociceptors, detect temperature, pressure and chemical signals. They have a high threshold for activation and only send messages when the body is at risk of harm.

If skin temperature rises above 40 degrees Celsius or dips below 15 degrees Celsius, thermal nociceptors start to fire. If pressure exceeds three kilograms per centimetre squared, or if the skin stretches or tears, mechano-nociceptors kick into action. And if cells become damaged and start leaking their contents, chemical nociceptors switch on.

A rapid response to nociceptor activation is crucial. If you put your hand in a flame, your body needs to react in fractions of a second. Nociceptors send their signals to the spinal cord, which manages the first step of the response. It can process some of the information without the brain, triggering a rapid withdrawal reflex. This is the very simplest form of damage control, and even primitive animals sense and respond to harm in this way. But pain is more than just a reflex.

As the hand pulls away from the fire, the signal from the nociceptors passes up the spinal cord towards the brainstem. In the brain it enters the cerebral cortex, responsible for cognition and consciousness. Processing here ties the incoming sensory signals to memory and emotion, producing the complex feeling of pain. The unpleasant experience that follows helps us to remember harmful activities and to avoid them in the future.

Sensing danger

The pain pathway is the body's built-in alert system

Processing
The brain processes the incoming signals, storing information about the danger and the context so that it can be avoided in future.

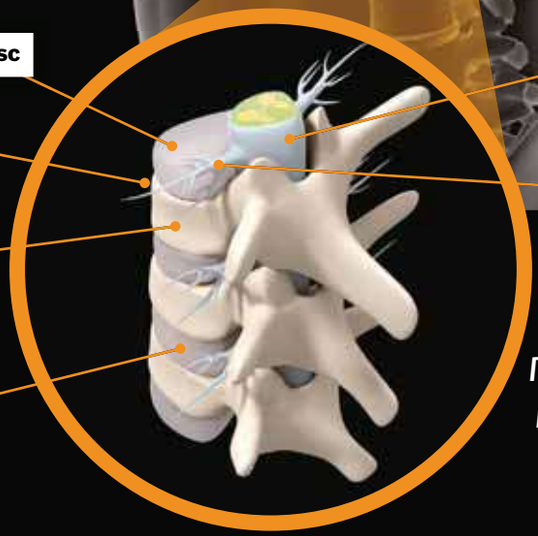
Transmission
Electrical signals pass along the nerves towards the spinal cord.

Nociception
Nerves in the skin detect danger, like extreme temperature or pressure.

Withdrawal
Neurons in the spinal cord activate motor neurons in the arms, rapidly contracting the muscles to move the hand away.

Reflex
Before the signals even reach the brain, neurons in the spinal cord trigger a withdrawal reflex.

Chronic pain
Damage to the pathway can cause parts to activate at the wrong time, causing long-lasting pain that's hard to treat.



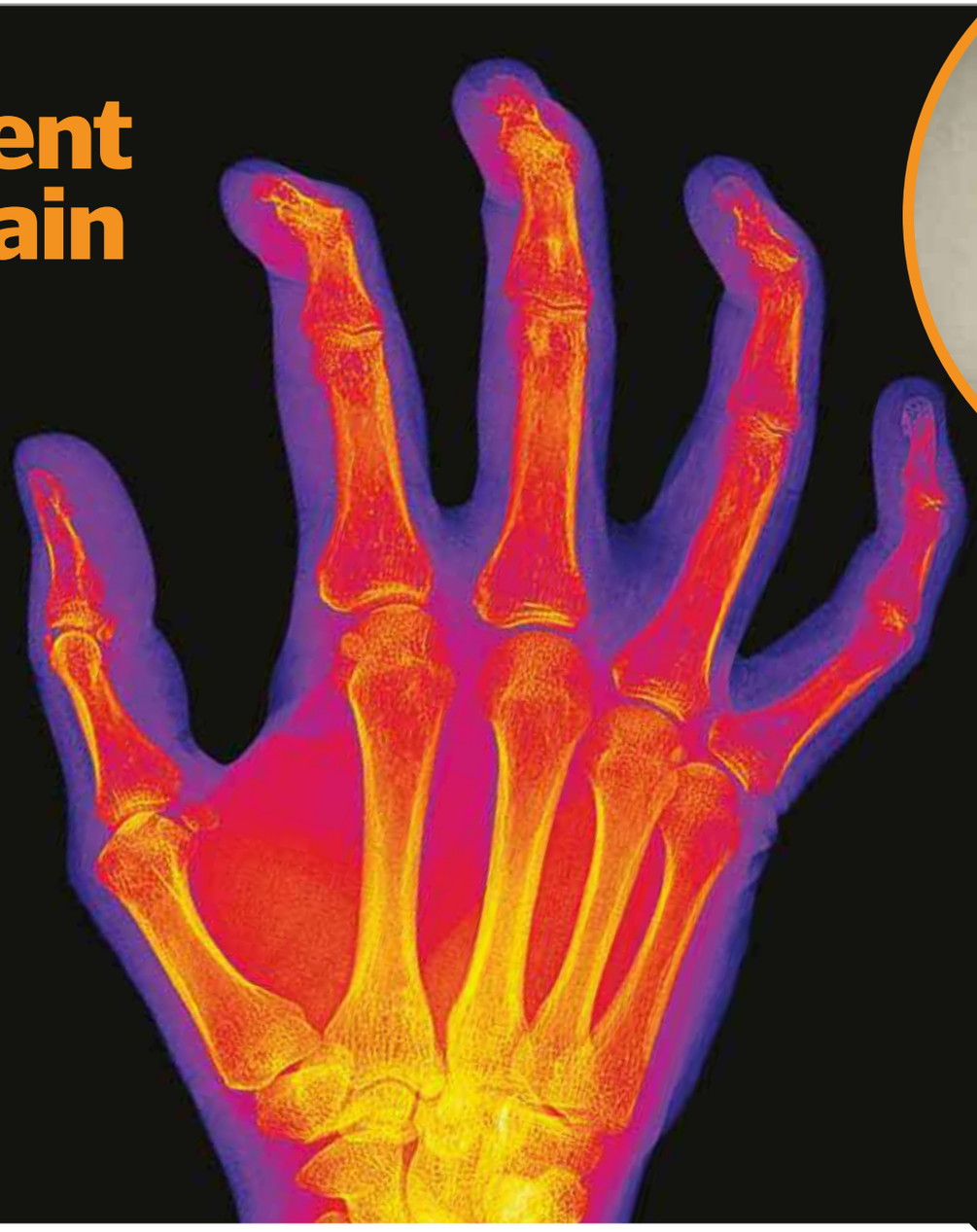
"Your body needs to react in fractions of a second"

The different types of pain

Pain can be short-term (acute) or long-term (chronic). It can be mild, uncomfortable, distressing or debilitating. It can feel achy, dull, raw, sharp, stabbing, throbbing or burning. It might be constant or it might come and go. But beneath these different experiences, all pain falls into two main categories: nociceptive and neuropathic.

Nociceptive pain is the normal response to tissue damage. Pain nerves sense extreme temperature, extreme pressure or harmful chemicals and they send signals to the brain. This alerts us to danger, encourages us to rest the injured area and reminds us to avoid the situation in the future.

Neuropathic pain, by contrast, does not serve a useful purpose. It is the result of nerve damage. Certain injuries, illnesses and infections harm pain-sensing neurons, and if the body cannot make repairs, they can start to misfire. The nerves send pain signals when there shouldn't be any pain, and the brain can't tell the difference. This type of pain is particularly challenging to treat.

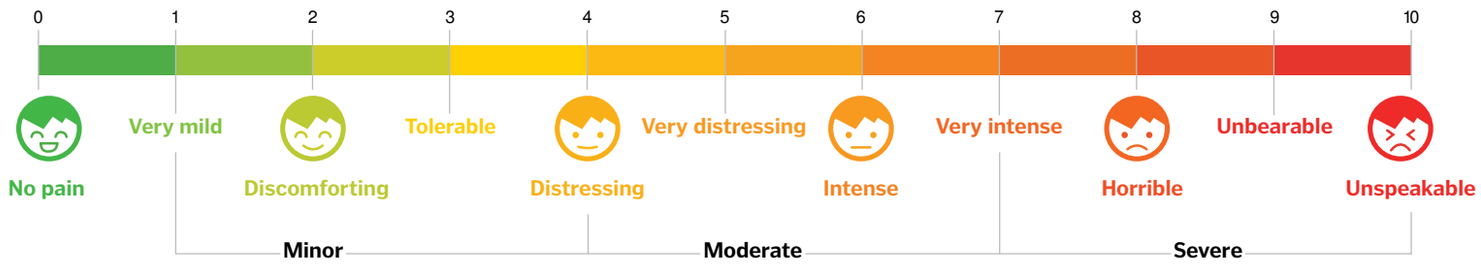


The arthritic joints in the hand on the right cause nociceptive pain

Can we measure pain?

How do you convert the subjective experience of pain into cold hard numbers? One of the first attempts was to use a dolorimeter, a device that would push or burn the skin until the patient said 'ouch'. This would reveal their pain threshold; the amount of pressure or heat they could tolerate. Today, the most common measure of pain is simply to ask someone how they're feeling and how much it hurts on a scale of one to ten. However, scientists at the University of Colorado have been using brain scans to make this more scientific.

Using a dolorimeter-like approach, they applied heat to the skin, but instead of waiting for people to say 'ouch', they watched their brains. In total, 114 people took part in the study, which also included scientists from three other US universities. Each person experienced a range of different temperatures, which revealed a signature pattern of brain activity that predicted the level of physical pain they felt. The pattern differed from emotional pain and decreased with painkillers, providing an objective way to see how much something really hurts.



Some studies have suggested that women feel pain more intensely

Acute vs chronic pain

Spot the difference between these two major types of pain

Acute		Chronic
Resolves after the illness or injury gets better	Time	Continues long after the injury heals
Nerve activation in response to actual tissue damage	Cause	Not always clear
Alert system to avoid damage and allow time to heal	Purpose	No clear biological purpose
Focused on tackling the underlying cause of the pain	Treatment	Focused on managing pain and minimising the impact

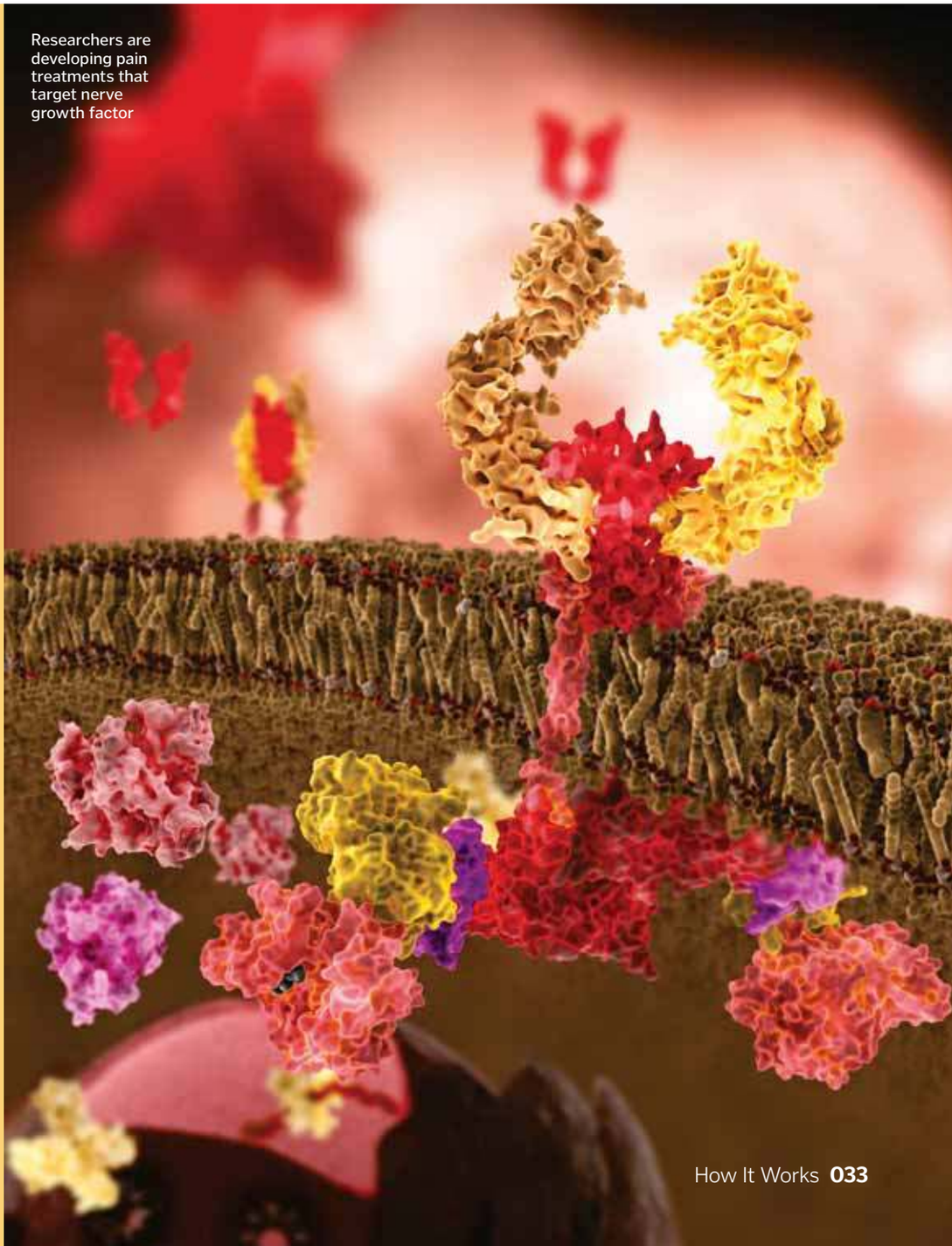
Treating chronic pain

Over-the-counter painkillers tend to target inflammation, which means they are not always particularly useful for chronic pain. Opiate painkillers, like codeine and morphine, can stop pain messages reaching the brain, but they are addictive and their effectiveness decreases over time, so they are not recommended for long-term treatment. Other options include antidepressants and anticonvulsants; these actually change the brain's chemistry, but they don't work for everyone.

The pharmaceutical industry has been looking at a chemical produced by the brain called nerve growth factor (NGF). NGF changes the pain sensitivity of nerves, and blocking its activity in animals has been shown to help to reduce pain, but trials conducted in humans in 2010 had dangerous side-effects, including loss of blood to the bones. There is still a lot of work to do to find out whether they are safe to use.

Physical and psychological therapy can help to provide some distraction, but many people struggle daily with chronic pain. Without a cause for doctors to treat, it can be extremely hard to manage.

"Nerve growth factor changes the pain sensitivity of nerves, helping to reduce pain"



Researchers are developing pain treatments that target nerve growth factor

Killing pain

Damage to our tissues causes mechanical and chemical changes that activate pain-sensing neurons. The neurons send signals to the spinal cord, which relays them to the brain. Painkillers try to block this process by interfering with it at different stages.

The most common over-the-counter painkillers attack the very start of the pain-sensing chain. Non-steroidal anti-inflammatory drugs (NSAIDs) – like ibuprofen – try to remove some of the chemical signals that activate pain-sensing neurons. They do this by interfering with an enzyme called cyclooxygenase (COX). COX makes chemical messengers called prostaglandins, which promote inflammation. Blocking COX dampens the inflammatory response, relieving the pain.

The next step in the pathway is the transmission of pain signals towards the spinal cord. Local anaesthetics work here. For nerve cells to fire they need to transport sodium ions across their membranes. These carry a charge, which sets up the electrical signal. Local anaesthetics block the channels that transport the ions, stopping pain signals in their tracks.

The strongest painkillers, the opioids, work on the next part of the pathway: preventing signals getting to the brain. This group includes codeine, morphine and the illegal drug heroin. They act on the spinal cord and brainstem to stop pain messages passing through.

Finally, there are the general anaesthetics, which work on the very last link in the chain. They stop the brain being aware of pain by interfering with the way that nerve cells pass signals to each other. Each kind of painkiller has advantages and disadvantages for different situations.

Painkillers interfere with the way our body senses and responds to damage

People who don't feel pain

Very rarely, people are born without the ability to feel pain. A defect in a gene called SCN9A makes it impossible for their pain-sensing nerve cells to transmit signals. This makes it impossible for them to tell when hot becomes burning, when cold becomes freezing or when pressure becomes crushing.

The SCN9A gene codes for a protein that makes a part of a structure called a sodium channel. Sodium ions carry the electrical signals along nerves, and these channels control their movement. With the mutation in the gene, the channels don't fit together and the pain-sensing neurons can't fire. While this might sound like a superpower, but being unable to sense pain makes people with these genetic faults much more likely to do themselves harm.

Faults in the SCN9A gene switch pain-sensing nerve cells off by terminating protein translation

Gate control theory

Have you ever stubbed your toe and immediately reached down to grab your foot? Or burnt your finger and instinctively put it into your mouth? This is gate control theory at work.

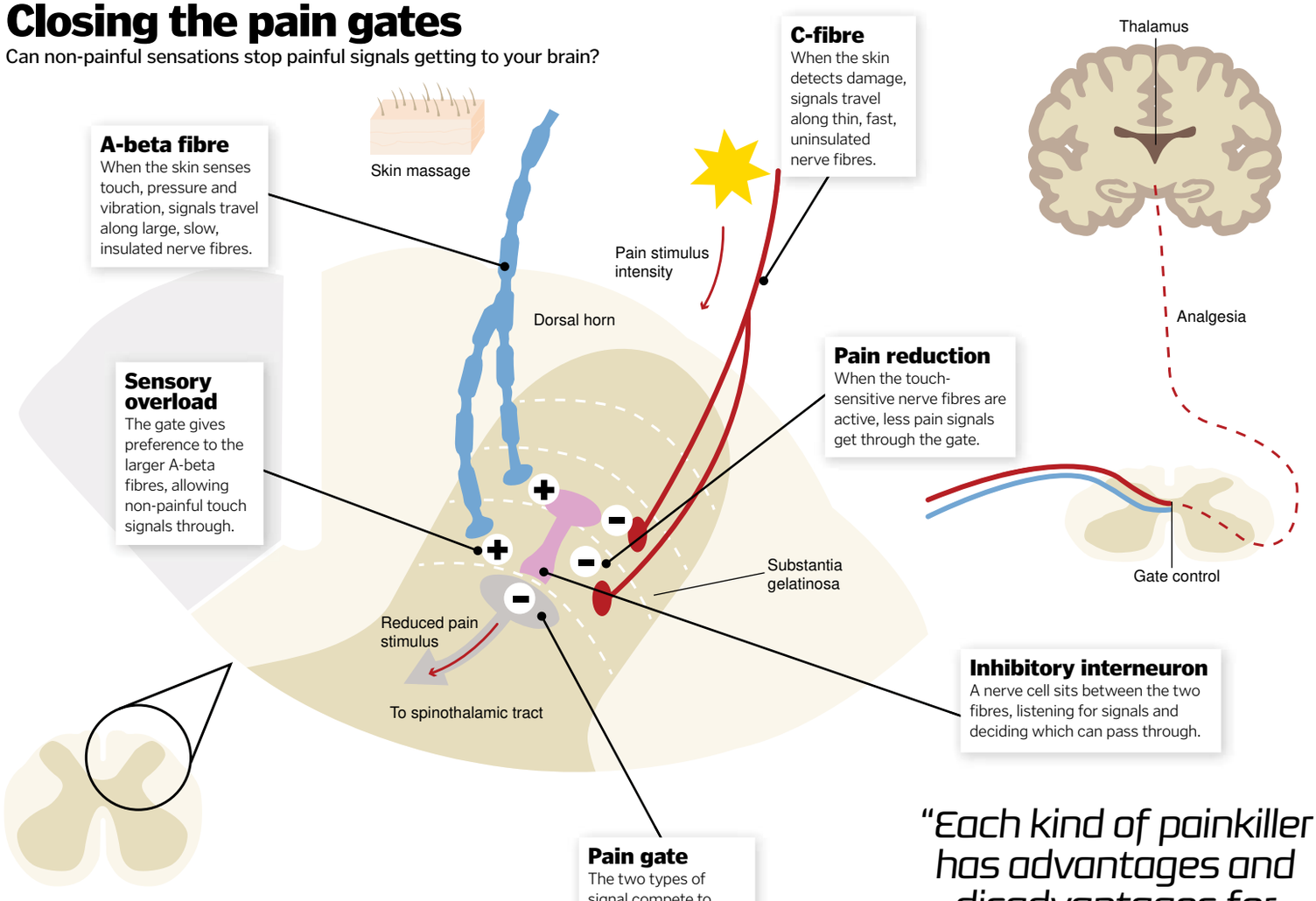
Pain signals travel from the site of an injury towards your brain along thin nerve fibres. As they enter the spinal cord they compete for bandwidth with the other nerves that are also trying to send messages to your brain. This includes larger fibres that carry non-painful signals, like pressure and touch. Both the painful and non-painful signals are trying to reach the projection cells of the spinal cord, but there's a gatekeeper in the way.

The gatekeeper is an inhibitory neuron. It listens for signals from both the pain fibres and the sensory fibres and decides which can send its signals to the projection neuron. When a pain signal arrives on its own the interneuron lets it through the gate, but when a sensory signal is passing the gate the pain signal closes. So if you put pressure on your stubbed toe it can stop some of the pain signals from reaching your brain, naturally blocking out the unpleasant feeling.

Rubbing or holding an injury can override some of the pain signals before they reach your brain

Closing the pain gates

Can non-painful sensations stop painful signals getting to your brain?



A-beta fibre
When the skin senses touch, pressure and vibration, signals travel along large, slow, insulated nerve fibres.

C-fibre
When the skin detects damage, signals travel along thin, fast, uninsulated nerve fibres.

Sensory overload
The gate gives preference to the larger A-beta fibres, allowing non-painful touch signals through.

Pain reduction
When the touch-sensitive nerve fibres are active, less pain signals get through the gate.

Inhibitory interneuron
A nerve cell sits between the two fibres, listening for signals and deciding which can pass through.

Pain gate
The two types of signal compete to pass through the 'gate' into the spinal cord.

"Each kind of painkiller has advantages and disadvantages for different situations"

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What are microRNAs?

The 'junk DNA' that controls at least 30 per cent of our genes

When scientists sequenced the human genome, they expected to find hundreds of thousands of genes. As it turned out, we only have approximately 25,000, and most of the rest of our genetic code is 'junk'. Or so we thought.

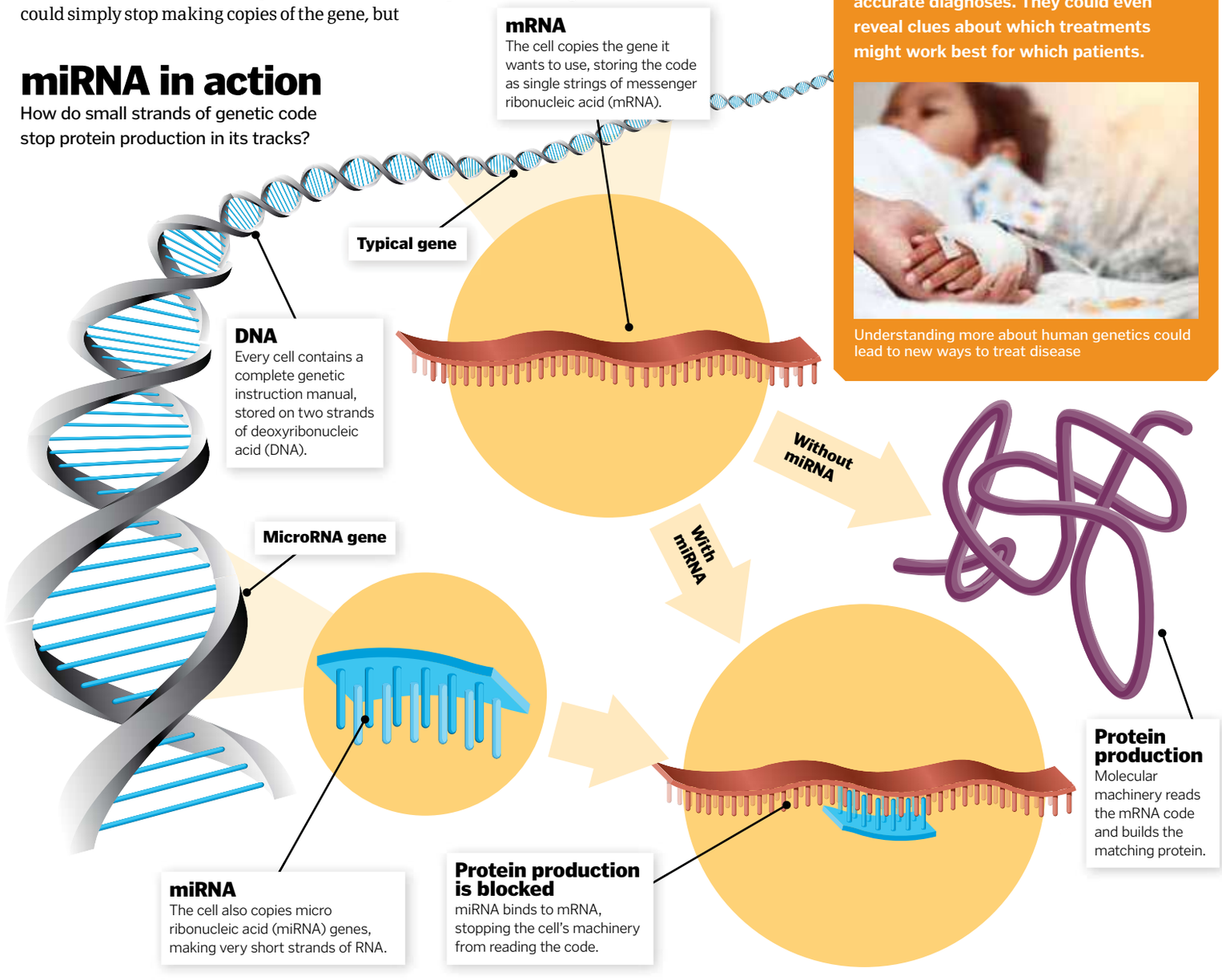
Genes are sections of genetic code that carry the instructions to build proteins; they are the manual for the human body. When cells want to make a protein, they make lots of temporary copies of its gene. These copies pass out of the cell nucleus and into molecular machines, which read the sequence and assemble the protein. For the cell to work properly, getting the timing right is crucial.

When the cell wants to turn production off, it could simply stop making copies of the gene, but old copies hang around in the cell and can carry on making protein. This is where microRNAs (miRNAs) come in. These short stretches of genetic code come from the 'junk' part of our genome. There are around 2,200 of them, and they fine-tune protein production.

As with normal genes, the cell makes temporary copies of their code, but these copies don't tell the machines to make protein. Instead, they stick to the copies of protein-coding genes and stop them passing through the machinery. They can also 'tag' the copies for destruction, telling the cell to get rid of the unwanted code. miRNAs keep protein production in check, making sure cells have exactly the right amount of protein at the right time.

miRNA in action

How do small strands of genetic code stop protein production in its tracks?



© Getty; Illustration by Ed Crooks

The links between miRNA and disease

Our cells are like finely tuned machines; changing the levels of different proteins can completely change their behaviour. By interfering with protein production, microRNAs help to control critical cell activities, like metabolism, development and cell death. However, if the balance isn't right this can lead to disease.

Scientists have discovered that patterns of miRNAs change in certain types of cancer, and it's possible that this affects how tumours develop. miRNAs also seem to be important in heart disease, neurological diseases and the immune system.

In the future, testing miRNA levels could help doctors to make faster, more accurate diagnoses. They could even reveal clues about which treatments might work best for which patients.

Understanding more about human genetics could lead to new ways to treat disease

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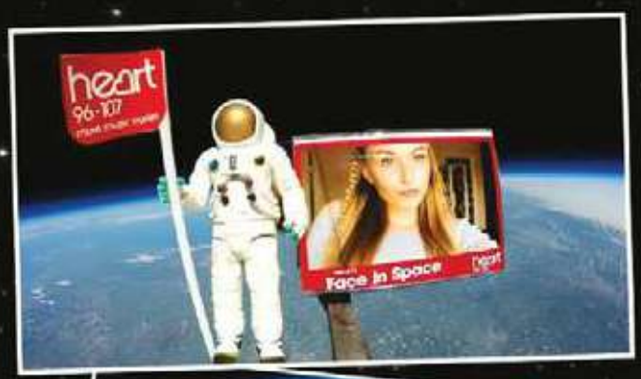

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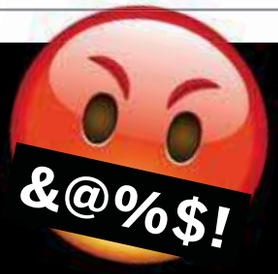
The science of rudeness



Road rage, interrupting colleagues, talking at the theatre – we are all familiar with rude behaviour, but do you know the science behind bad manners?

Rudeness can cause inadvertent but serious harm

The performance of medical teams can be detrimentally affected by rude interactions

Have you ever had someone say something rude and moments later you think of the perfect witty response? You're not alone. But dwelling on these interactions and that snappy comeback distracts your brain and affects your ability to focus, recall facts, piece together information and remember things properly. Doctors, surgeons and nurses are no different – their cognitive function and performance can be seriously impacted by rude behaviour, which is no joke when other people's lives are in their hands. One study found that medical teams exposed to a staged rude encounter earlier in the day performed less well when asked to diagnose and treat a medical mannequin compared to teams that experienced a neutral staged encounter. It's estimated that error due to rudeness could account for over 40 per cent of medical mistakes.

You might get ruder with age

Older people can lose their inhibitions, making them more likely to say exactly what they're thinking

Scientists have discovered that rudeness impacts your brain's frontal lobes; the regions responsible for your working memory. As we get older, these parts of our brain start to deteriorate and can impair 'executive functioning' – the ability to plan into the future and control the things you say and do. Research in the field has used tests such as the Stroop test, where participants are asked to say the colour of the ink and not read out the word. For example, being shown the word 'red' written in green ink and expected to say the colour green. We struggle to do this because we have to get our brain to override the automatic impulse to read, so it's a good test on the ability to control and inhibit your own thoughts. Older people are less able to do this, which may be why they can sometimes be more blunt and make inappropriate remarks.

Bad manners are contagious

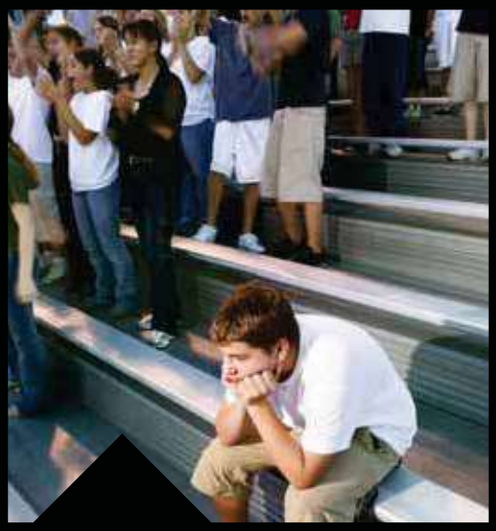
Other people's behaviour can spread like a disease and influence our own

Forget trying to avoid catching germs on the Underground – there's something else passing between the hordes of morning commuters that you could catch: bad manners. It only takes one person to shove past you or say something nasty and you're instantly at a higher risk of passing on negativity to other people. Research investigating the contagiousness of rudeness has shown that workers are more likely to respond with hostility to customer emails after watching videos of employees interacting aggressively. When paired with partners on a graduate course, students who thought their first partner was rude would act more rudely in turn towards their second partner. This social phenomenon happens with positive interactions too, meaning you can feel happier around happy people.

Negative workplaces are less efficient

Nastiness at the office can cause you to lose focus and spend less time working

Rudeness in the workplace can have dramatic effects on your productivity. Whether someone is insulting you, ignoring you, or withholding information from you to make your job harder, research suggests that after encountering incivility in the workplace you are more likely to spend more time slacking off. This can be because you're more likely to spend time avoiding rude people and more time thinking about leaving the company, in addition to the loss of motivation and morale that comes with working in a difficult environment.



Bad manners partly evolved to protect us from disease

Communities may subconsciously separate themselves from strangers

New theories suggest that where diseases are common, individuals are ruder to strangers. From an evolutionary perspective this makes sense: new people might bring new diseases, and being rude will keep them at a distance. Research suggests that countries with a higher disease prevalence are also countries where people are more likely to show prejudice towards people from other countries. Particularly in locations where deadly disease is common, individuals are more likely to be focused on the welfare of their own group rather than being polite to strangers.

Dough chemistry

The simple science behind one of the world's oldest recipes

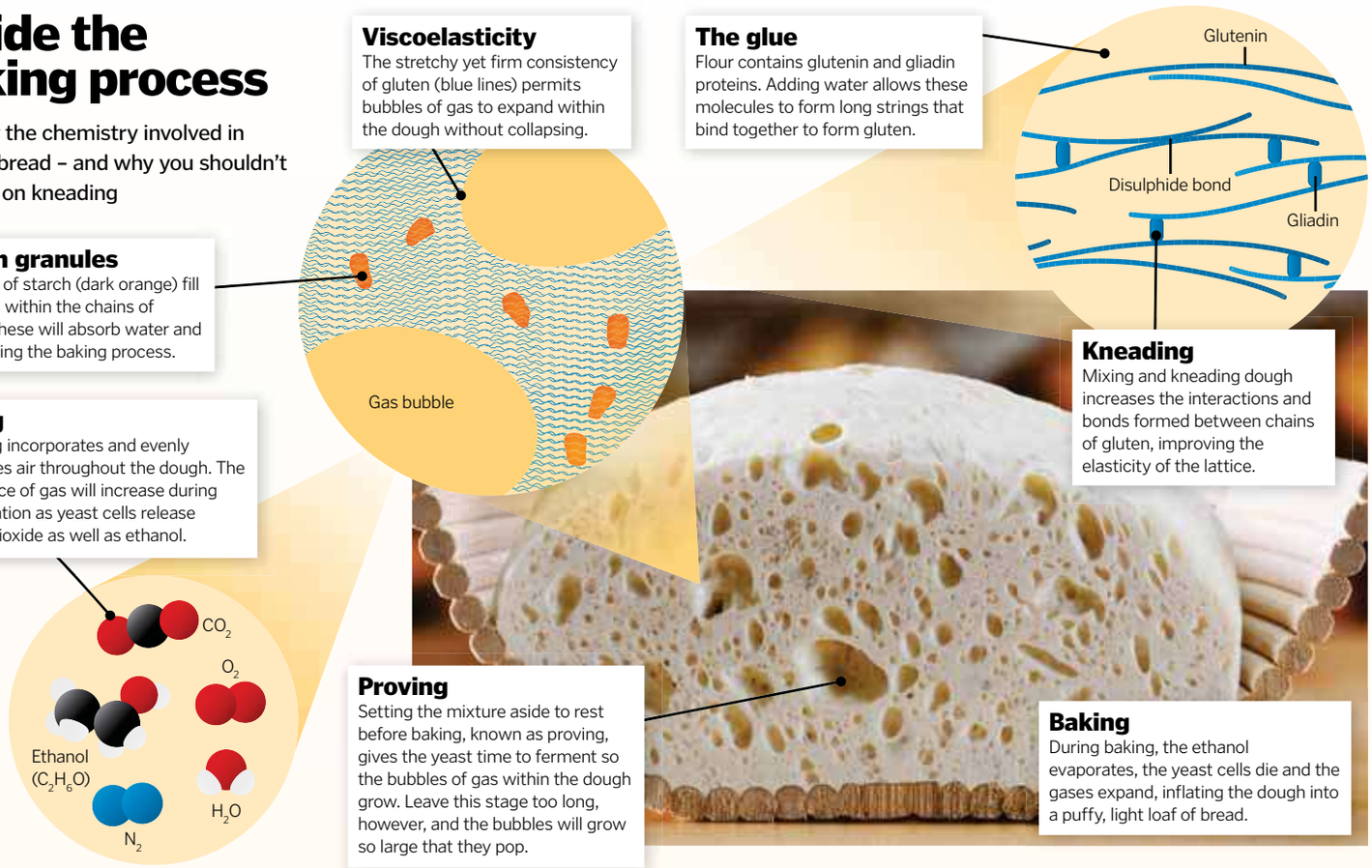
Humans have been baking bread for a long time, with some scholars suggesting it existed in a primitive fashion at least 30,000 years ago. By the time of the ancient Egyptians bread was not much different than it is today. Both the basic ingredients of flour, yeast, water and salt, and the process of kneading, rising and baking, have remained largely unchanged for thousands of years.

The molecular star of this staple food item is a protein complex called gluten. After grains such as wheat, rye or barley are milled into a flour they retain groups of proteins called glutenins and gliadins. When water is added to the flour, these proteins are able to mix and form multiple types of bonds, including disulphide bonds. Gluten is the product of this cross-linking process between glutenins and gliadins, and its special properties create a light, fluffy loaf.

In dough, gluten forms a lattice of interlinked strings of protein, making it both strong and flexible. The result (when the dough is well mixed) is a viscoelastic structure. This describes a material that is strong enough to resist some force but also elastic enough to return to its original dimensions once it has been stretched. This attribute is key to permitting bubbles of gas to form and expand within the dough, as the gluten lattice will readily move aside for expanding bubbles but won't collapse while doing so. This means that plenty of gas can be stored and during baking will expand, producing a large, light loaf of delicious bread.

Inside the baking process

Uncover the chemistry involved in making bread – and why you shouldn't skip out on kneading



Alternative doughs

Although nothing in the world of baking can be called a perfect science, the harmony of gluten and yeast in the bread-making process is likely one of the closest examples. Yet despite their importance in making an ideal loaf, there is a growing consumer demand for doughs that avoid using either gluten or yeast.

To contemplate omitting one of these ingredients we first have to consider what role they perform in a traditional dough. Yeast is a single-celled organism that produces carbon dioxide as it grows, adding valuable gas into the dough and helping it to rise. A substitute for this process is to rely on baking soda, which releases gas via a chemical process. Gluten is a little trickier to replace, as the protein lattice has near-perfect properties for supporting bubbles of gas. Thus, most gluten-free breads retain less gas and are denser than traditional bread.

Gluten-free breads lack a strong and elastic protein lattice and so retain less gas

WOLVES IN THE WILD

Words by **Scott Dutfield**

Discover why these animals are nature's top dog and what it's like to be a member of the pack

Wolves are one of the most widespread carnivores alive today. Spread across North America, Europe and Asia, grey wolves (*Canis lupus*) are one of the most adaptable predators on Earth. Also known as the timber wolf, the dominant grey wolf shares ancestors with other members of the world's many wolf subspecies. It is thought they, along with their cousins the dire wolves (*Canis dirus*), evolved in Eurasia and crossed the Bering Land Bridge to North America 400,000 years ago.

Wolves are first and foremost carnivores. Equipped with powerful jaws packed with sharp teeth, they have an appetite for large ungulates such as moose, elk and deer. On average, wolves require at least 1.7 kilograms of meat per day to survive but will often feast on around four kilograms when possible. Due to the nature of the preferred meal, this daily diet isn't constantly supplied. Therefore, wolves go through periods of feast and famine, grabbing their meals as and when they can. As mainly opportunistic killers, wolves may also scavenge the remains of another creature's kill when hunts aren't fruitful.

For several thousand years humans and wolves coexisted peacefully. Though the exact time and location is still debated, it's believed wolves were first domesticated between 10,000 and 15,000 years ago. Both man and beast worked together to form a lethal combination – in a mutualistic relationship, man used wolves to help hunt and for protection, while wolves benefited from easy access to food and shelter. This partnership was so effective some have argued that human and wolf hunting groups may have heavily contributed to the extinction of the world's megafauna, which occurred around the time of wolf domestication. Since then, after thousands of years of selective breeding, humankind's historical kinship with wolves has resulted in a huge variety of dog breeds.

"For several thousand years humans and wolves coexisted peacefully"

By howling, wolves are able to communicate over large distances with one another and warn off other packs

However, in more recent times our love of wolves has turned sour. While some wolves are hunted for their fur or as trophies, others are targeted in order to protect our livestock, which would otherwise become easy wolf prey. Continued human persecution has led to some wolf species teetering on the brink of extinction.

Wolf relatives

True wolves and wolf-like canids are all members of the Canis genus and can be found all around the world

Breeding season for grey wolves occurs from late January to March

Animals
Kingdom: Animalia

Vertebrates
Subphylum: Vertebrata

Mammals
Class: Mammalia

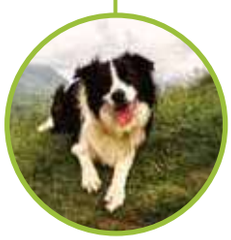
Carnivores
Order: Carnivora

Land Carnivores
Infraorder: Fissipedia

Dogs
Family: Canidae

Weasels and relatives
Family: Mustelidae

Foxes
4 Genera



True dogs
Genus: Canis

Other Canids
5 Genera

Canis lupus

To date, 12 subspecies of *Canis lupus* have gone extinct. Today, there are 26 extant subspecies.

Coyote
Canis latrans
North and Central America

Dingo
Canis lupus dingo
Australia

Grey wolf
Canis lupus
North America, Europe, Asia, Middle East

Red wolf
Canis rufus
Southeastern US

Ethiopian wolf
Canis simensis
Ethiopia

Black-backed jackal
Canis mesomelas
East and southern Africa

Pack life

Like humans, wolves form tight, long-lasting bonds with their relatives

Wolves usually form packs of around six to ten individuals, but this can vary from anywhere between two and 36 wolves depending on birth and survival rates. At the head of the pack hierarchy are the breeding pair, who lead their offspring, and occasionally other unrelated wolves, as a pack.

Past studies had popularised the idea of an 'alpha' wolf leading a pack of subordinate 'beta' and 'omega' individuals. It was thought that beta wolves, the second-in-command, would be ready to step in and lead the pack should an alpha die. These younger members of the pack would also challenge an alpha in the event they become too old or weak. The omegas, it was proposed, were the lowest-ranking wolves in a pack; usually the weakest individuals and those that face the most aggression from those at the top. These studies, however, were based on captive wolves and were not a true representation of wild wolf behaviour.

In reality, the wolf pack family is less hierarchical and behaves more like a human family unit with the parents in charge. That's not to say there is no intra-pack conflict. Scientists studying wild wolves have witnessed dominance behaviour between adult males of the same pack, where one male would repeatedly pin down another. It is thought that this aggression was between father and son, perhaps a signal that the younger male would soon be breaking away to start his own pack. Lone 'dispersing' wolves have been known to travel hundreds of kilometres away from their parental pack's territory in search of a mate to start a new pack with.

Communication among members of the pack is key to their success. They use three different 'languages': sound, including howls, whimpers, and growls; scent, such as scat and pheromones; and body language.

The most well-known form of wolf communication is of course their iconic howl. Howling or vocal communication in a pack can be used for a variety of reasons. Wolves will vocalise to ward off other packs, assert dominance or to assemble other pack members. Howls are also used during pack rallies, where wolves play with and embrace each other to strengthen social bonds. Together, a pack will wander through territories spanning up to 2,500 square kilometres, methodically leaving scent markings to create the perimeter of the pack's territory and deter other packs from encroaching.

Strength of the pack

The combination of wolves' apex predator anatomies and their strong social bonds make the pack a force to be reckoned with

Litter
Wolves typically have one litter a year. After a gestation period of 63 days a pregnant female gives birth to an average of four to six pups.

Den
Alpha females will dig dens in which to give birth to their pups. Sometimes they will reuse an abandoned den of other animals.

Play fighting
Playing helps young pups develop the skills they will later need for hunting and improves their bonds with their siblings and other pack members.

"The lone wolf dies but the pack survives"
Wolves share responsibilities among the pack, including hunting and looking after the pups.

Howling
Wolves howl to communicate with other pack members – and to warn off rival packs – even when they are several kilometres apart.

Dominance
If two wolves of the pack become aggressive, usually the subordinate wolf will give up before a real fight begins. It will demonstrate submission by rolling onto its back.

Trekking
Wolves tend to stick to either natural or human-made paths and roads, walking up to 48km a day.

"Scientists have witnessed dominance behaviour between males of the same pack"

Hunting
Wolf packs work together to take down large prey such as elk. A common tactic is to separate a vulnerable creature from its herd before going in for the kill.

Skull
At the top of a wolf's skull is the sagittal crest, which firmly anchors its powerful jaw muscles.

Nose
There are an estimated 280 million olfactory receptors in a wolf's nose, making their sense of smell about 100-times better than humans.

Fur
A wolf's fur coat is filled with guard hairs up to 10cm long, which repel the elements and provide vital insulation.

"My, what big teeth you have!"
Wolves are carnivores and as such have formidable fangs to tear through flesh. Their strong jaws provide a bite force of over 2,000N.

Eyes
Wolves have excellent night vision. A light-reflecting layer called the tapetum lucidum reflects light that misses the photoreceptors back towards the retina.

Out of the woods?

Once over-hunted, are wolves returning to their roots?

The original range of the grey wolf has been reduced by around one-third globally. One of the prominent reasons for wolf population decline is the fragmentation of habitats, as it affects their prey species. Disrupting the delicate balance of predator and prey can have dramatic effects on an ecosystem. It works like a seesaw: by removing wolves from one side of the seesaw, the deer numbers on the other side go up. This becomes a problem for the environment the deer live in due to overgrazing. The opposite scenario, where wolf populations increase, is equally problematic, and this is where their conflict with human begins.

When the wolves' natural food sources run low – either due to disease or as a result of human hunting – they are forced to look for food elsewhere. Wolves will naturally target the weakest and slowest members of a herd, so livestock grazing in fields become easy pickings. This inevitably leads to the persecution of wolves by farmers as they seek to protect their livelihoods. As a result, these canines have been branded as the 'big bad wolf'. However, when predator and prey populations are balanced they are less likely to cross into human habitats in search of alternative meals.

As human habitats have expanded, wolves' territories have become increasingly fragmented. Primarily due to the threat they pose to livestock, wolves have faced eradication across North America and Europe, Germany in particular. However, since 1970 legal protection for wolves across the globe has helped combat this decline, and increased conservation efforts are helping to rebuild wolf populations.

However, not all of these projects work as planned. Despite being reintroduced to the east coast of North America in 1987, the critically endangered red wolf (*Canis rufus*) continues to decline and is predicted to become extinct within eight years unless more is done to help.

Contrary to fairytales, wolves have no interest in humans and will actively avoid us. This makes tracking them an evidence-based endeavour. Using wolf scat, track marks and camera traps, biologists can monitor the population sizes, different packs and most importantly their health, with DNA collected from scat samples acting as a genetic ID tag for each wolf.

Wolves eat a range of small mammals, including rabbits and beavers

Odd one out

If you were to combine the legs of a deer, the body of a fox and the face of wolf, what you might find yourself looking at is the maned wolf (*Chrysocyon brachyurus*). Though commonly referred to as a wolf, genetic analysis has revealed that these long-legged creatures are in fact neither true wolves nor foxes, instead belonging to their own genus: Chrysocyon.

Despite its unusual appearance, the maned wolf's diet also separates it from the wider wolf pack. These canines are omnivorous and have a particular interest in lobeira fruit – known as 'fruit of the wolf' – which, along with other fruit and vegetables, comprises half of their diet.

It is believed that their unusually long, slender legs evolved in response to the high grasslands found on the savannahs they roam, their limbs enabling them to look out for prey. The common name of this wolf comes from its prominent maned neck, the hairs of which stand on end when it senses danger.

The maned wolf is found around central and eastern regions of South America

Returning to Yellowstone

In 1995, wolves were famously reintroduced to Yellowstone National Park, US, after being eradicated in the 1920s. Wolf populations originally fell due to human hunters, but the result of losing these large carnivores almost destroyed the park's food chain. Without wolves, prey such as elk go unchecked. As elk populations continued to soar their excessive overgrazing caused significant damage to the park.

To help redress the predator-prey balance, a reintroduction programme was established to put the wolf back to work. The US Fish and Wildlife Service, along with a team of Canadian biologists, relocated wolves from neighbouring populations in Canada between 1995 and 1996. It's thought there are now roughly 480 wolves in 75 packs distributed within the greater Yellowstone ecosystem, proving the project worked.

Radio collars were used to track the movements of the first reintroduced generation

Tracks can be used to identify wolf territories

Scat samples can provide valuable information about a wolf's health and diet

"Contrary to fairytales and fables, wolves have no interest in humans and will actively avoid us"

Wolves form strong bonds within their packs, creating a comparable family unit not dissimilar to our own

Learn more

To learn more about wolves, in particular how to monitor them, Biosphere Expeditions offer wolf conservation expeditions in Lower Saxony, Germany. For more about Biosphere head to **www.biosphere-expeditions.org** or follow them on Twitter **@biosphereexped**.

How plants transport water

Plants might look static, but they're hydraulic engineers that are always at work

Water is vital to plants. From growth and photosynthesis to flowering and keeping their leaves in shape, they need it for everything. To make sure they're getting enough of the stuff, plants have evolved an efficient water transportation system.

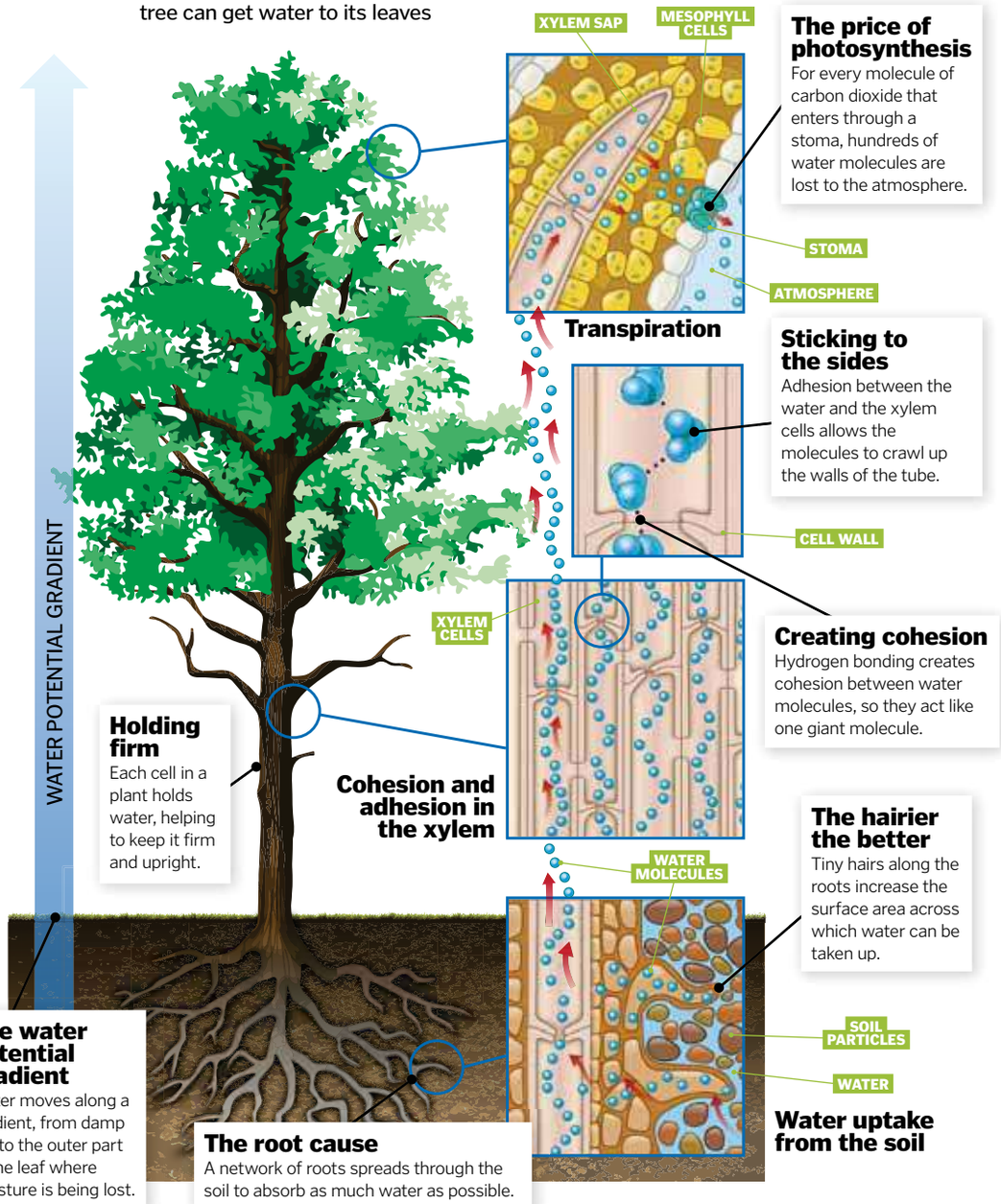
A plant's roots take in water and minerals from the soil as they move from the damp ground into the dry plant through a permeable layer. The longer they grow, the more surface area they have for absorption, and, amazingly, they can even grow in the direction of the wettest patches – a process called hydrotropism.

While we have a heart to pump blood around our body, plants have to rely on physics to get water from the ground to their leaves. Xylem tubes, made out of dead cells, are strong tubes running the whole length of the plant. As openings on the leaves (known as stomata) open to allow carbon dioxide in, water evaporates through transpiration. More water molecules are drawn up from further down the xylem tube to replace it and to balance out the difference in pressure, sticking to the molecules ahead of them and producing an effect similar to sucking on a drinking straw. On sunny and windy days, water evaporates from the leaves at a higher rate, so more is pulled up from the roots to counteract this.

Without enough water, plants struggle to stay upright and begin to wilt

From the ground up

With this effective system, the tallest tree can get water to its leaves



The price of photosynthesis
For every molecule of carbon dioxide that enters through a stoma, hundreds of water molecules are lost to the atmosphere.

Sticking to the sides
Adhesion between the water and the xylem cells allows the molecules to crawl up the walls of the tube.

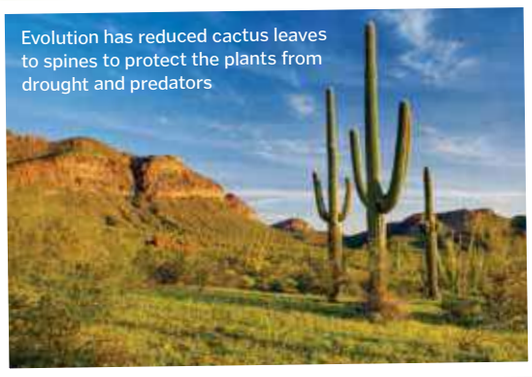
Creating cohesion
Hydrogen bonding creates cohesion between water molecules, so they act like one giant molecule.

Holding firm
Each cell in a plant holds water, helping to keep it firm and upright.

The hairier the better
Tiny hairs along the roots increase the surface area across which water can be taken up.

The water potential gradient
Water moves along a gradient, from damp soil to the outer part of the leaf where moisture is being lost.

The root cause
A network of roots spreads through the soil to absorb as much water as possible.



Evolution has reduced cactus leaves to spines to protect the plants from drought and predators

Living without water

When there's no rain and the soil is drying up, plants have to adapt to survive. By keeping their stomata closed during the hottest part of the day they can reduce transpiration, but with no carbon dioxide entering the leaves they can't photosynthesise to produce sugars. When temperatures drop at night, stomata can be opened to let carbon dioxide in while losing as little water as possible.

Some plants are used to coping with water scarcity. These species grow extremely long roots, and their leaves are either fleshy and covered in a waxy layer or reduced to spines to minimise water loss through evaporation. When rain does arrive, some species can store the water in tubers or bulbs under the ground for later use.

Strength in numbers

One ant is strong – a colony is almost unstoppable

Working together, ants can carry prey much bigger than themselves

Ants are incredibly strong insects; leafcutter ants can carry 50 times their own weight, and Asian weaver ants have been observed carrying things 100-times heavier than themselves. When they work together their strength is formidable; their social lifestyle is one of the keys to their success.

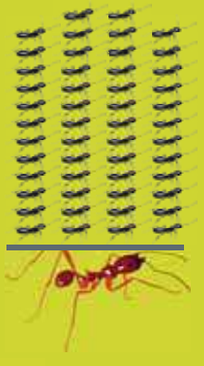
Part of this lifting ability comes from their small size. With light exoskeletons, muscle that has to be used to support the body in larger animals can instead be dedicated to pulling and carrying. Were ants to be scaled up to a bigger size their weight would increase more than their muscle strength, reducing their lifting power significantly.

While being small is the ant's main advantage, it does have other anatomical adaptations that help with its life of hauling food and building materials. Compact bodies and gradual changes in limb width towards joints minimise weak points. Microscopic surface textures around joints are thought to help brace body parts against each other against the force of heavy loads or reduce stress when the hard exoskeleton is forced against soft tissue. Sticky, expanding footpads allow the insects to balance on smooth surfaces and even travel upside down while keeping hold of their loads. Strong mandibles with quick pincer actions allow ants to grab hold of food and keep all their legs free for a quick journey back to the colony.

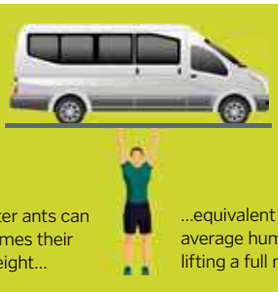
How much can they lift?

Average human
The average person can deadlift something close to their own body weight.

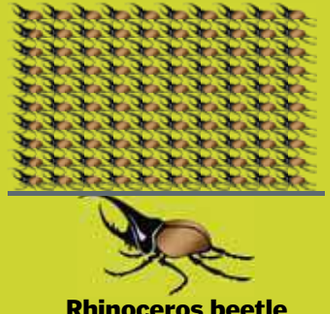
World's strongest man
The deadlift world record currently stands at 500 kilograms – around the weight of a male polar bear.



Ants
Leafcutter ants can lift 50 times their body weight...



...equivalent to the average human lifting a full minibus



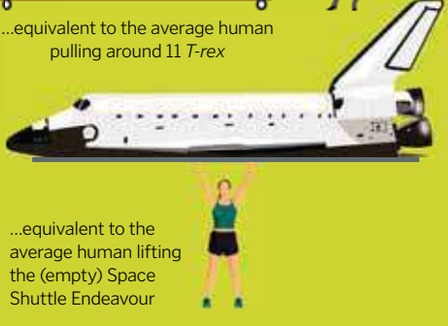
Rhinoceros beetle
Male Hercules beetles can lift 100 times their own weight...

...equivalent to the average human lifting a bull elephant

Dung beetle
The taurus scarab is capable of pulling up to 1,141 times its own body weight...

...equivalent to the average human pulling around 11 *T-rex*

Oribatid mite
Despite their microscopic bodies, oribatid mites can lift 1,180 times their own weight...



...equivalent to the average human lifting the (empty) Space Shuttle Endeavour

Animal super strength

Iron jaws
Overtaking spider silk, limpet teeth have been found to be the strongest biological material known to humankind.

Firm grip
Coconut crabs have a grip strength ten-times greater than ours, meaning they can crush hard foods and fight off any attacker.

Bone-crushing bite
Saltwater crocs can bite with a force of 16,460N, over 3.5 times harder than the previous record holder, the spotted hyena.

Internal armour
Hero shrews have dense spines with interlocking vertebrae that mean they can survive being stood on by an adult human.

Tight squeeze
The California kingsnake delivers the highest constriction pressure relative to its size and can crush bigger snakes.

HEROES OF... ENVIRONMENT

Primatologist Jane Goodall changed the way we think about chimp behaviour

Jane now delivers talks around the world, accompanied by her toy monkey, Mr H

A life's work

For the love of chimps

1934
Valerie Jane Morris-Goodall is born in London, England, on 3 April to her engineer father and author mother.

1957
Jane travels to Africa for the first time and meets famous anthropologist and palaeontologist Dr Louis Leakey.

1960
Jane arrives at the Gombe Stream Chimpanzee Reserve in western Tanzania to study chimps.

1961
On 4 November, Jane observes the chimp David Greybeard making tools to extract termites from their mounds.

Jane Goodall

The woman who went to live with chimpanzees

Jane managed to get closer to wild chimps than anyone had before

From a very young age, Jane Goodall showed a natural fascination for animals and their behaviour. When she was just five years old she went missing for several hours, much to the worry of her parents, after following a hen into her coop to find out where eggs came from. Instead of being told off by her parents, Jane's curiosity was encouraged, and after reading *The Story of Doctor Dolittle* and the *Tarzan* novels it soon became her ambition to study animals in the wilds of Africa.

She eventually made it to the African continent when she was 23, and after meeting anthropologist and palaeontologist Dr Louis Leakey, she landed her dream job. Leakey wanted someone "with a mind uncluttered and unbiased by theory" to study chimpanzees in their natural habitat, and because Jane had no formal science qualifications he decided she would be the perfect person for the task. He sent her to Gombe in Tanzania to live among the chimps. Armed with just a notepad and a pair of binoculars, she began watching them from afar. "I wanted to learn things that no one else knew, uncover secrets through patient observation," said Jane. "I wanted to come as close to talking to animals as I could."

In just a year she had managed to get the chimps to accept her and allow her to get close enough to make some groundbreaking observations. Jane was the first person to witness chimps making and using tools and hunting and eating other animals – it was previously thought that they were vegetarian. She also noted that they have emotions and personalities much like us, as she watched them hug and kiss as well as fight and kill.

However, many in the wider, male-dominated scientific community were unwilling to accept the discoveries of an uneducated woman. Some even believed Jane had taught the chimps to use tools – "That would have been fabulous if I could have done that," laughed Jane – and criticised her for giving them names and personalities. "I didn't give them personalities, I merely described their personalities," she said.

Although she had no ambition to be a scientist, Dr Leakey insisted Jane studied for a PhD in ethology to give her research more credibility. She obliged, but only so she could go back to Gombe. There, she set up a research centre and spent the next 25 years making further important discoveries about our closest living relatives. Sadly, during that time she also observed the destruction of their habitat and subsequent decline in their population. Today she travels the world campaigning for wildlife conservation and educating the next generation of chimp champions.

> *"Jane was the first person to witness chimps using tools"*

THE BIG IDEA

Discovering humans are not the only tool makers

While Jane was observing the chimps in Gombe she noticed one of the males, who she had named David Greybeard, stripping leaves from a stick. He then pushed the stick into the hole of a termite mound and began using it to extract the termites and eat them. What Jane had witnessed was the first evidence that humans were not the only species on Earth to make and use tools. It was a truly groundbreaking discovery, and when she told Dr Louis Leakey what she had seen, he responded, "We must now redefine tool, redefine man, or accept chimpanzees as human!"

Jane's discovery redefined our fundamental understanding of what it is to be human

5 THINGS TO KNOW ABOUT... JANE GOODALL

1 She still has her first ever toy chimpanzee
Jane's father bought her a soft-toy chimp called Jubilee, a replica of a real chimp who was born in 1935 at London Zoo, England, for her first birthday.

2 She wanted to visit Gombe alone
When Dr Leakey first sent her to Gombe, Jane wanted to go alone. However, local authorities wouldn't let her travel without an escort so her mother travelled with her.

3 She married her photographer
Jane met her first husband, Baron Hugo van Lawick, when he was sent to Gombe by National Geographic to photograph her and the chimps. They married in 1964.

4 She called her only son Grub
Jane and Hugo had one son together, also called Hugo, in 1967, but to family and friends he was known as 'Grub'. Jane took inspiration from chimp mothers when raising him.

5 She spends about 300 days a year travelling
Jane has visited at least 60 countries, and for over 20 years a toy monkey called Mr H has travelled with her wherever she goes.

1962
Dr Leakey sends Jane to Cambridge University, England, to study for a PhD in ethology – the study of animal behaviour.

1965
Jane receives her PhD and National Geographic grants funds for the Gombe Stream Research Centre to be built.

1977
Jane establishes the Jane Goodall Institute for Wildlife Research, Education and Conservation.

1991
Jane and 16 Tanzanian students set up the Roots & Shoots global environmental and humanitarian education programme for young people.

2002
United Nations Secretary-General Kofi Annan appoints Jane to serve as a United Nations Messenger of Peace.

2004
Jane is made a Dame of the British Empire (the equivalent of a knighthood) at Buckingham Palace in London.

MEET THE iPHONE KILLER

Could the latest Huawei creation give Apple a run for its money?

Words by **Scott Dutfield**

Huawei aren't new kids on the mobile market block. Founded in 1987, this Chinese company produced their first phone, the C300, back in 2004. Since then their innovation has led them to challenge one of the world's biggest brands.

Earlier this year Huawei overtook Apple to become the second largest global smartphone maker. Hot on the heels of the world's number one, Samsung, Huawei are making waves with their newest creation: the Huawei P20 Pro.

It's been named 'Best Smartphone of 2018' by the European Hardware Association, and Technical Image Press Association (TIPA) named it this year's 'Best Photo Smartphone'. These accolades are, in part, thanks to the introduction of the first triple rear camera to grace the global market. The perfect selfie has become a hot commodity among the social media generation,

> *"Huawei overtook Apple to become the second largest global smartphone maker, and they're hot on the heels of Samsung"*

and in the age of Instagram, companies like Huawei are working to make sure every image is picture-perfect. Not only is it a record breaker in its number of cameras, the P20 Pro also houses the first built-in artificial intelligence (AI) processor. Part of their relatively new Kirin 970 chip (seen in the Huawei Mate 10 series), the P20 Pro also works with the AI to make sure you always capture the best possible pictures.

HIW travelled to the home of Huawei in China to see how the new P20 Pro fares in action. Visiting the metropolises of Shenzhen and Shanghai, we put the camera to the test while exploring the wealth of culture and scenery of some of China's tourist hotspots. It's safe to say that the P20 Pro was up for the challenge. With a launch-to-capture speed of 0.3 seconds, it never missed a beat when it came to grabbing the perfect shot.

The P20 Pro's camera captures landscapes in stunning detail, even in low light

The P20 Pro combines the power of three high-definition cameras – the first of its kind

Huawei invited **HIW** to their Shenzhen campus, home to their R&D Center

Innovative AI

Taking artificial intelligence offline makes the P20 a true pro

Several phones currently on the market use artificial intelligence technology, but in most cases this is accessed via the Cloud and requires an internet connection. Information from a smartphone is typically sent to a server to be processed, and then an answer is received. Huawei, however, has taken the broad applications of internet-assisted AI and created the world's first built-in smartphone AI computing platform, the Kirin 970. This AI processing chip houses a Neural Processing Unit (NPU) that takes inspiration from the way our brains learn.

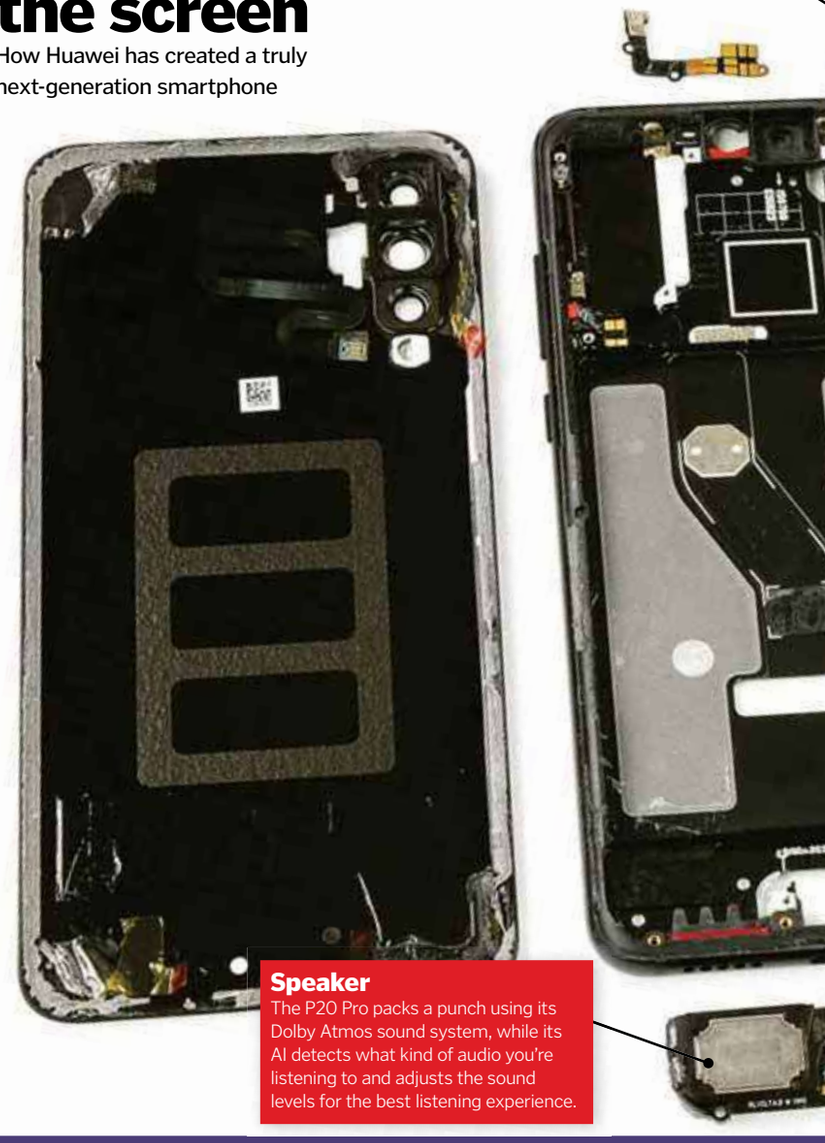
Recognition is one of the fundamental purposes of AI, whether it's your voice, face or location. The way the Kirin 970 does this is via its NPU. Images, for example, are recognised by its knowledge base, known as an inference engine. That image is then processed and compared with its knowledge base for recognition and an answer is given. So if you were looking at a dog through the camera, for example, it would analyse that image at between 17–33 frames per second and tell you you're looking at a dog.

It might seem strange to be impressed with a phone that can tell you what you're already seeing, but when that then affects camera settings or can give information about what you are looking at, it becomes increasingly advantageous. This high level of recognition and knowledge makes the potential for the chip boundless. In a test demonstration, the Kirin 970 processed 2,000 images per minute. This method of learning is also applied to facial and voice recognition.

The P20 Pro was co-engineered with Leica, a German-based manufacturer of premium cameras and sports optics products

Behind the screen

How Huawei has created a truly next-generation smartphone

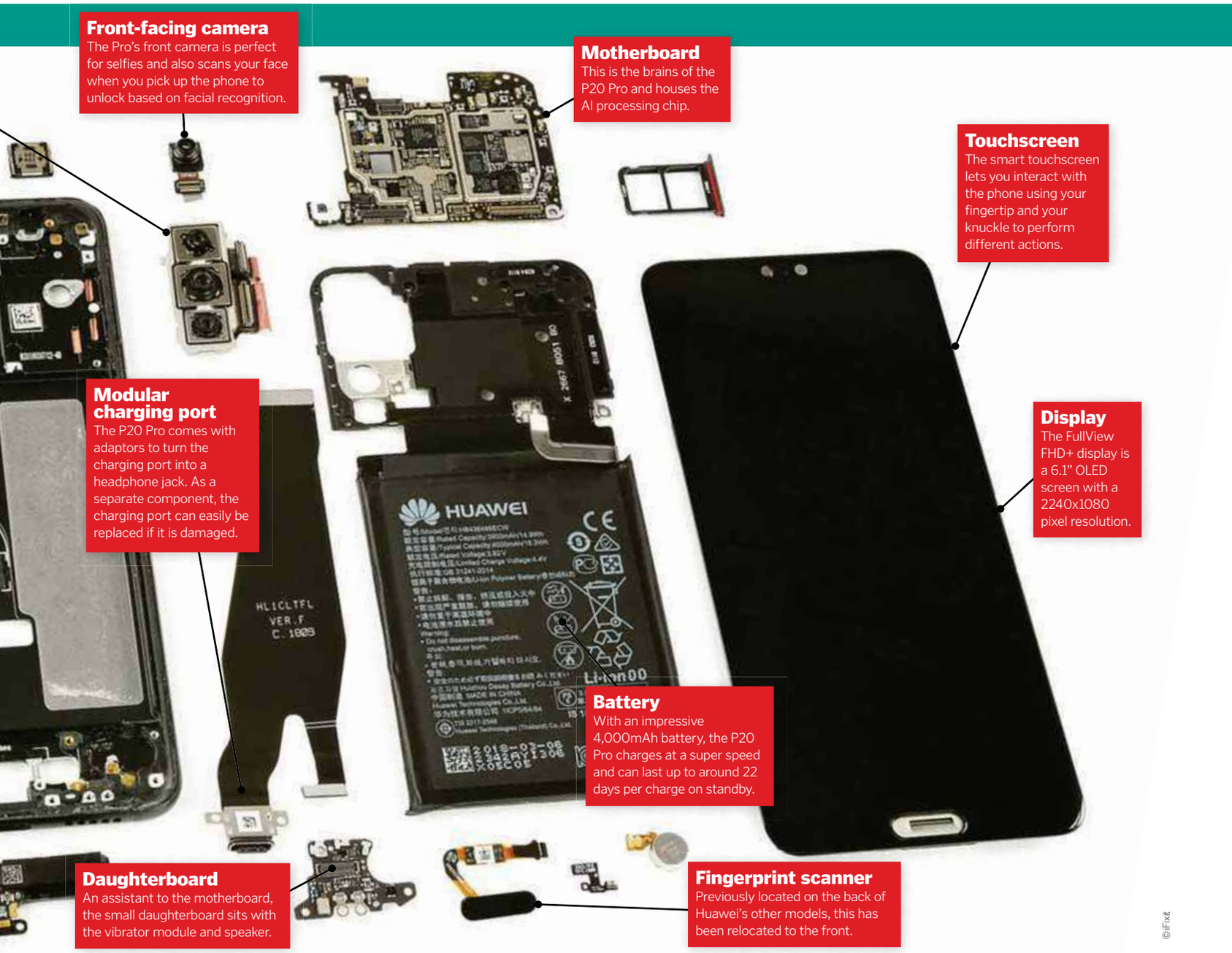


Leica triple camera
The P20 Pro features the world's first rear triple camera in a smartphone.

Speaker
The P20 Pro packs a punch using its Dolby Atmos sound system, while its AI detects what kind of audio you're listening to and adjusts the sound levels for the best listening experience.

Plus vs Pro

	iPhone 8 Plus	Huawei P20 Pro
Screen size	5.5" widescreen display	6.1" FullView display
Weight	202g	180g
Screen resolution	1920x1080 pixels	2240x1080 pixels
Battery life (talk time)	Up to 21hrs	Up to 25hrs
Memory capacity	64 or 256GB	128GB
Camera (front)	7MP	24MP
Camera (rear)	12MP	40MP



Front-facing camera
The Pro's front camera is perfect for selfies and also scans your face when you pick up the phone to unlock based on facial recognition.

Motherboard
This is the brains of the P20 Pro and houses the AI processing chip.

Touchscreen
The smart touchscreen lets you interact with the phone using your fingertip and your knuckle to perform different actions.

Modular charging port
The P20 Pro comes with adaptors to turn the charging port into a headphone jack. As a separate component, the charging port can easily be replaced if it is damaged.

Display
The FullView FHD+ display is a 6.1" OLED screen with a 2240x1080 pixel resolution.

Battery
With an impressive 4,000mAh battery, the P20 Pro charges at a super speed and can last up to around 22 days per charge on standby.

Daughterboard
An assistant to the motherboard, the small daughterboard sits with the vibrator module and speaker.

Fingerprint scanner
Previously located on the back of Huawei's other models, this has been relocated to the front.

Picture perfect

With the assistance of AI, the P20 Pro can see what you see

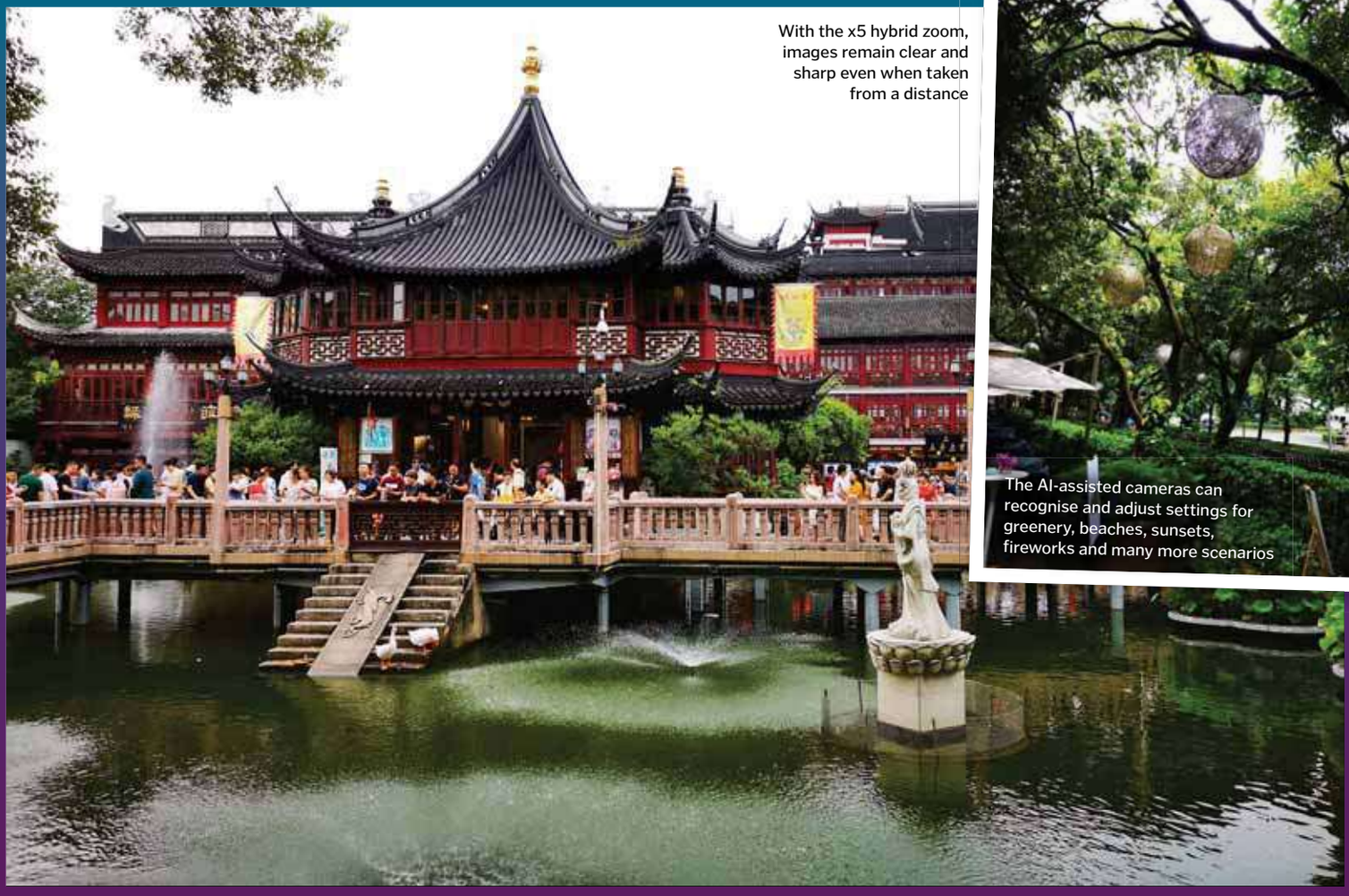
The most impressive aspect of the Huawei P20 Pro is by far its camera capabilities. With a whole host of features, settings and modes, the P20's cameras can accommodate any user's photography needs. The Pro is equipped with a rear-facing Leica Triple Camera consisting of an 8MP telephoto lens, 20MP monochrome lens and the main 40MP RGB lens, as well as the front-facing 24MP camera.

As the first system of its kind on a smartphone, the trio of rear-facing cameras can work together or individually with help from the supporting Kirin 970 AI hardware. When it comes to the camera, the P20's AI acts as a second pair of eyes on what you want to capture. Through the lens, the P20 Pro is able to recognise 19 different categories of objects or scenes such as food, portraits and waterfalls. In doing so, it will then change the camera setting to suit what you are shooting, such as adjusting the exposure or colour balance. It will even identify the horizon and display a line guide when capturing landscapes to help make sure that your shot remains straight. We thought the most professional-looking photo autocorrect is the Pro's ability to produce a pixel-perfect 'bokeh' background blur in a portrait shot.

"The P20's AI acts like a second pair of eyes on what you want to capture"

The built-in AI assist also works as a stabiliser for long-exposure shots. Smartphones aren't known as the best method of taking images in low light. To take the perfect picture of a night-time scene, the camera sensors need an extended exposure. In order to not be affected by shaky hands, camera shutters are typically only open for less than a second. This reduces the amount of light entering the lens and thus reduces the quality of the image.

In night mode, the P20 Pro can open the camera shutter for up to six seconds at different exposures. These exposures are married together to form the best-quality image. In order to maintain a focus image for that length of time the built-in AI works to compensate for any shakes in the photographer's hands.



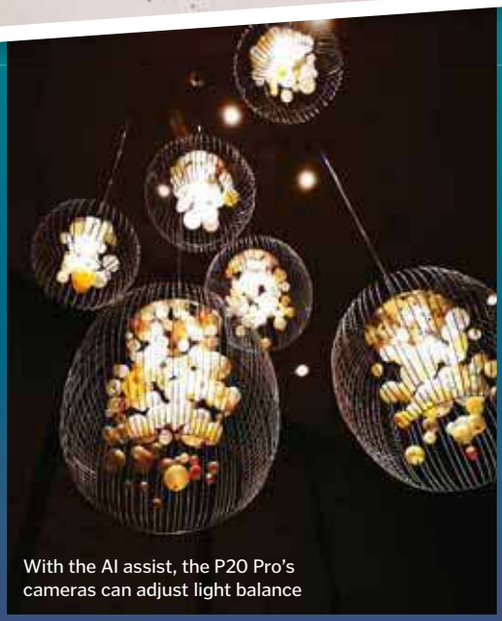
With the x5 hybrid zoom, images remain clear and sharp even when taken from a distance

The AI-assisted cameras can recognise and adjust settings for greenery, beaches, sunsets, fireworks and many more scenarios

Longer exposure time and AI stabilisation in night mode creates sharp images even in low light

The 40MP camera captures shots with fantastic light and definition

With different picture modes you can boost or soften the intensity of colours



With the AI assist, the P20 Pro's cameras can adjust light balance

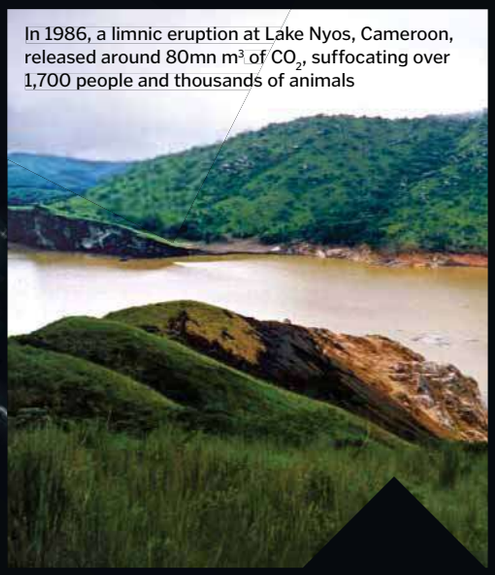
Colours appear vibrant in the automatic camera settings

Screenshot saga

We've all wanted to screenshot something on our phones, but remembering or being able to press several buttons at the same time can be awkward. Well, the P20 Pro, along with previous models, makes it a whole lot simpler: with a 'knock knock' on the screen with a single knuckle it will take a screenshot. You can also hold your knuckle down and then free draw a section of the screen to capture a partial screenshot. By knocking twice with two knuckles, the P20 Pro will begin recording the following actions on your screen, similar to the screen record on an iPhone. Though not a high-tech feature on the phone when compared to the AI assist, sometimes it's the simple things that make a big difference.

Peculiar power sources

With an increasing awareness of our finite fuel resources, researchers are investigating how we can extract energy from some of the most unlikely sources



In 1986, a limnic eruption at Lake Nyos, Cameroon, released around 80mn m^3 of CO_2, suffocating over 1,700 people and thousands of animals

Exploding lakes

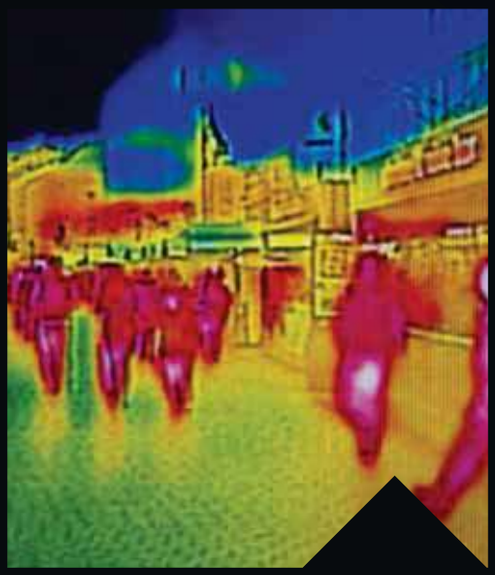
So-called 'exploding lakes' contain massive reservoirs of methane and CO_2. Under normal conditions the water's density keeps the gasses trapped below, but when a lake's temperature (and therefore density) changes the gasses can violently erupt with a cloud of deadly, suffocating gasses called a limnic eruption. However, harnessing these dangerous substances could both save lives and provide power. The KivuWatt project in Rwanda extracts methane from Lake Kivu and sends the gas via a pipeline to a power plant to generate electricity.

Parties

Imagine hitting the dance floor to your favourite songs and knowing that while you were dancing you were helping to power homes? Club Watt in The Netherlands is doing just that by using floor vibrations to power the lights. The company Energy Floors have created tiles that contain an electromechanical system, transforming small vertical movements – when they're stepped on – into a rotating movement, which drives a generator positioned below to produce electricity.

Coffee grounds

Globally, over 2 billion cups of coffee are drunk each day. But rather than binning the leftover grounds, what if we could use them as fuel? Bio-bean are a UK company that have turned this idea into a business, collecting waste coffee grounds from businesses and turning them into various biofuels and biochemicals. By removing moisture from the grounds and compressing them into pellets, the company can create coffee 'logs' that customers can use instead of traditional wood on fires.



Body heat

Buildings can be heated efficiently by harnessing the body heat of crowds – particularly those in shopping centres and train stations. In Stockholm Central Station, Sweden, the body heat of around 250,000 passengers a day is used to heat a nearby office block. In the station's ventilation system, heat exchangers transfer the thermal energy from the air to water in the pipes, which is then pumped to the neighbouring office's heating system.

Poo power

It might sound gross, but this is one power supply that will never run out! When bacteria feed on faeces under anaerobic conditions they produce methane and carbon dioxide gas, which can be stored and used as fuel. Some companies even process human waste into a hygienic solid fuel that can be used as a replacement for coal.

Jellyfish

Current technology limits the amount of energy we can collect and store from solar power, but scientists are now investigating how we can use 'biosolar' sources. Golden jellyfish host large amounts of algae-like organisms – which photosynthesise very efficiently – within their tissues. By harvesting the photosynthesising 'reaction centres' of these organisms scientists could create much more efficient biosolar panels.

Restarting hearts

How defibrillators use electric shocks to bring struggling hearts back to life

Your heart has a built-in pacemaker that keeps its muscle cells beating in time. A patch of cells called the sinoatrial node send electrical signals through the heart in rhythmic waves. You can hear the gentle 'lub. dub' rhythm of its co-ordinated beats in your chest. But sometimes the pacemaker loses control, the muscle cells stop working together and the heart starts to fibrillate.

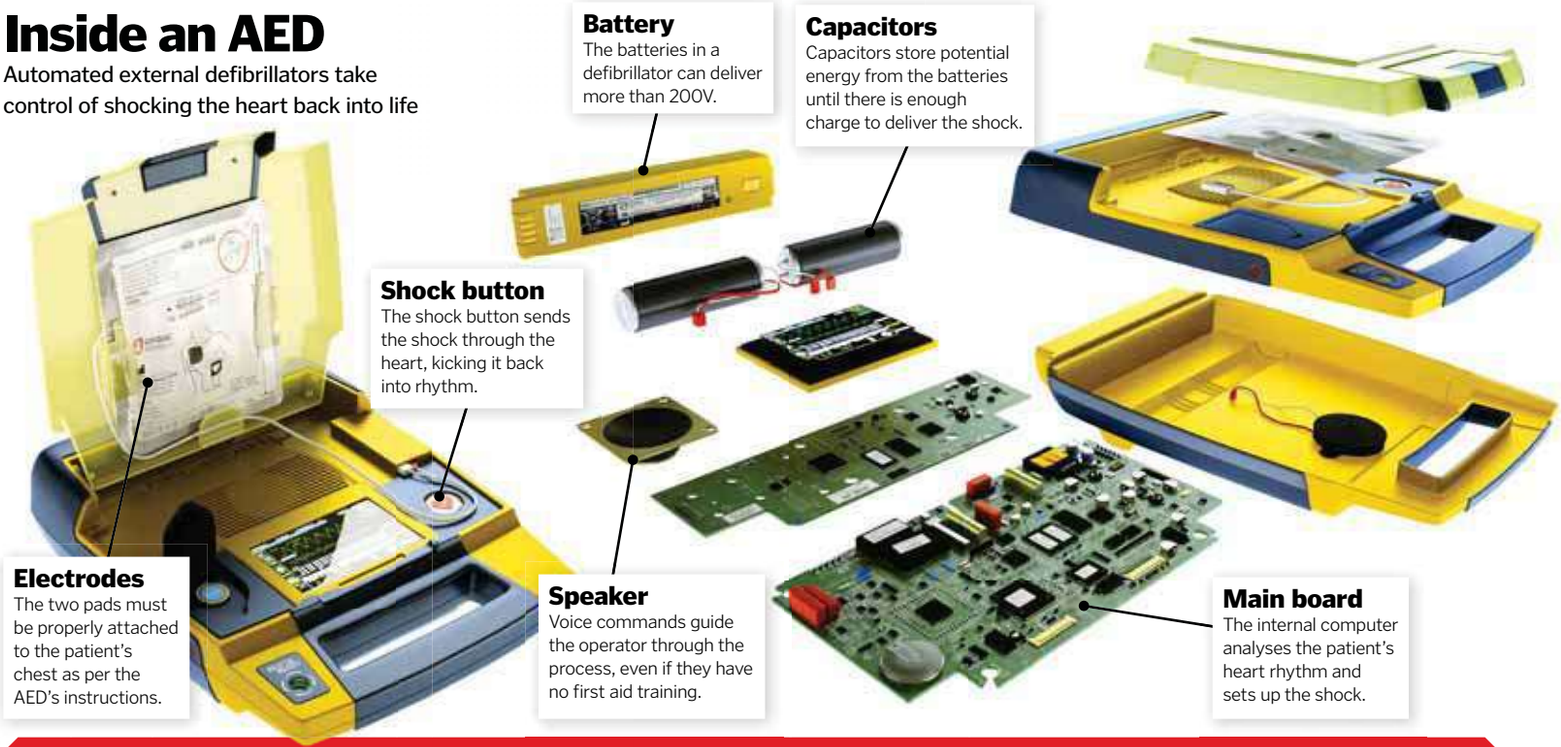
Rather than contract in orderly waves, a fibrillating heart wobbles and falters, meaning blood can't get around the body as normal. This is where defibrillators come in. They give the heart a high-energy electric shock, resetting the muscle and allowing the sinoatrial node to take back control.

If someone's heart is in trouble, the first step is to diagnose the problem using an electrocardiogram. This machine reads the heart's electrical activity, which dictates the voltage and timing of the shock required. Paddles are then placed on the chest wall: one above and to the left of the heart and one below and to the right. Then capacitors store the required charge before releasing it into the paddles, through the chest and across the heart.

It takes an expert to operate a manual defibrillator, like the ones in ambulances and hospitals, but many places now store automated external defibrillators (AEDs), which allow untrained people to deliver the same treatment. Using two sticky pads, AEDs pick up heart activity and use an algorithm to work out the best course of action, then they guide you through the process. Finding your nearest AED in an emergency could save someone's life.

Inside an AED

Automated external defibrillators take control of shocking the heart back into life



Battery
The batteries in a defibrillator can deliver more than 200V.

Capacitors
Capacitors store potential energy from the batteries until there is enough charge to deliver the shock.

Shock button
The shock button sends the shock through the heart, kicking it back into rhythm.

Electrodes
The two pads must be properly attached to the patient's chest as per the AED's instructions.

Speaker
Voice commands guide the operator through the process, even if they have no first aid training.

Main board
The internal computer analyses the patient's heart rhythm and sets up the shock.

Shockable rhythms

Defibrillators can't fix every heart problem; some heart rhythms are shockable and others are not.

Shocks work best when the heart's pacemaker cells have lost control of the heartbeat. In ventricular tachycardia, sometimes called v-tach, the heart is still trying to beat, but it can't push blood around the body. In ventricular fibrillation, known as v-fib, the heart shakes instead of contracting. For both of these rhythms, a shock helps the pacemaker cells to take control of the heart muscle and restart a normal heartbeat.

Pulseless electrical activity (PEA) and asystole do not respond to shocks. In PEA, the heart is producing the right electrical activity but there is no pulse. In asystole, there is no electrical activity at all; this is sometimes called flat-lining. Adrenaline injections and CPR can help here, but if the heart has stopped completely a shock can't restart it.

Not all heart rhythms will respond to a defibrillator shock

The future of shopping

Amazon Go's smart store means you'll never have to queue again

While Amazon has revolutionised the way we shop with its online service, the retail giant clearly thinks there is still a future for shopping outside of cyberspace. In January, the first bricks and mortar Amazon Go convenience store opened to the public in Seattle, US. However, unlike any other shop, this one lets you pick up the items that you want and pay for them without having to wait in clogged queues for a cashier.

No, we're not simply talking about self-checkout tills. This futuristic store uses a high-tech surveillance system that Amazon calls 'just walk out technology'. Using computer vision, hundreds of cameras monitor the store from every angle, allowing machines to 'see' what is in front of them and determine what objects are. This allows the store to not only follow the shopper but identify everything they pick up. This is then added to a virtual cart and automatically billed to their account when they leave the store.

However, this system is sophisticated enough to also track when you pick up an item (for instance, to consult its ingredients list) then put it back on the shelf. This is because the futuristic store is also fitted with numerous other detecting devices, likely including weight sensors in the shelves.

All of the information the store's many sensors collect is analysed in the same way Amazon Echo recognises voices, with machine learning working over the cloud – harnessing the power of the tech firm's massive data centres – to calculate your purchases. However, the process is not entirely automated. Behind the scenes, there are still some human employees helping to train the algorithms and double-check they've identified the correct products. People are also employed to prepare fresh food items, restock the shelves and to check shoppers' IDs for buying alcohol.

Customers scanning their phones to enter Amazon Go as it opened to the public on 22 January 2018

Banks of cameras and sensors in the ceiling track shoppers' purchases

Grab-and-go shopping

Amazon's super-smart stores are the closest thing to legal shoplifting

"Hundreds of cameras monitor the store from every angle"

1 Gaining entry
To begin shopping, scan the Amazon Go app on your phone at one of the entrance's turnstiles. A sensor will read your app's unique QR code.

2 Smart surveillance
Hundreds of cameras – including regular RGB lenses, as well as depth-sensing cameras – monitor customers' movements using computer vision.

3 No-pressure shopping
Pressure plates on shelves help the store's computer system track when you have picked up an item or put it back.

4 Next-gen barcodes
Some products, in particular fresh sandwiches and salads, are labelled with dotted codes that help the cameras identify them.

5 No checkout queues
Once you've finished shopping you simply walk out the store – you don't even have to scan the app again before you leave.

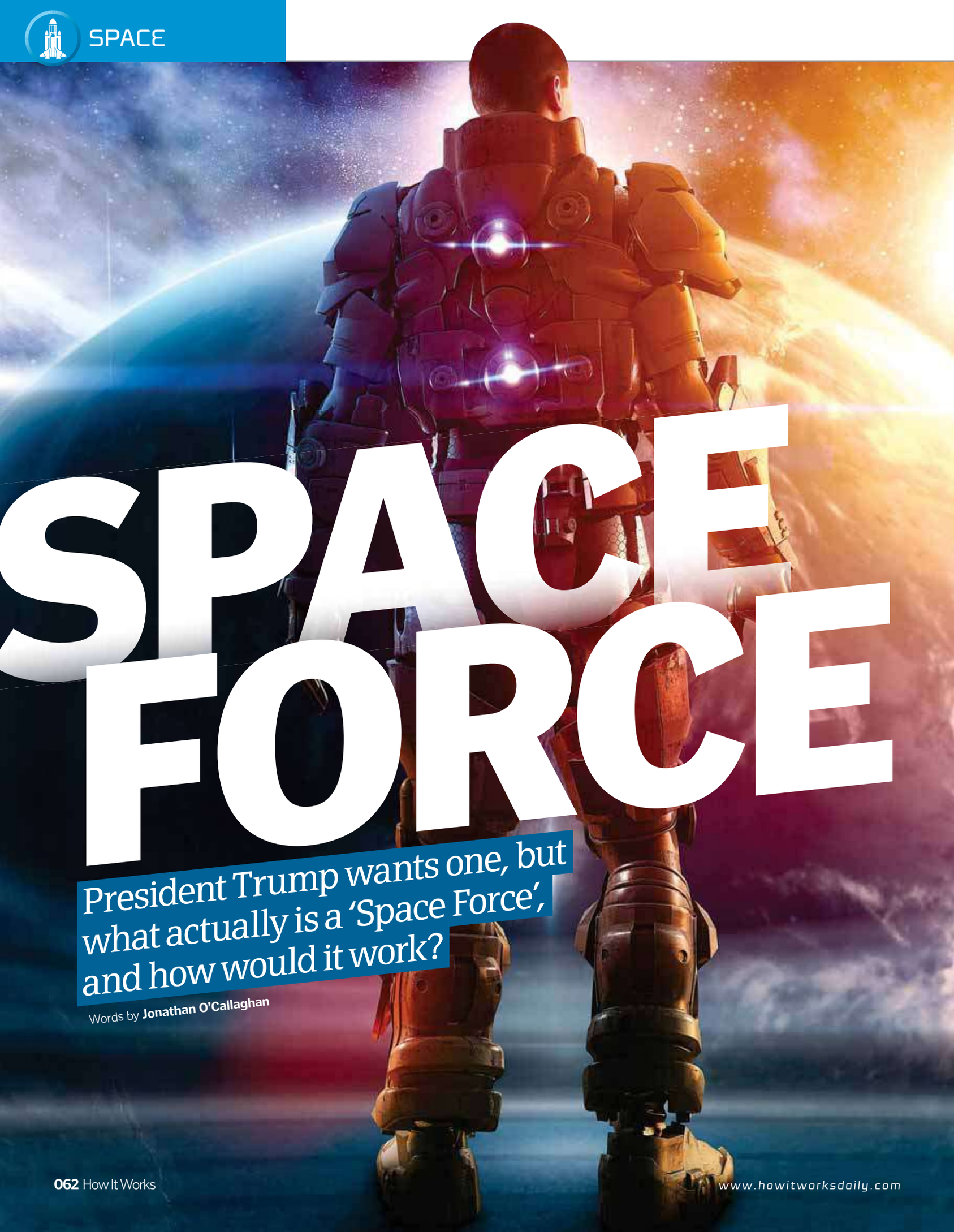
6 Pay on the Go
Once you leave the shop your bank account will be charged and an electronic receipt will be sent to your Amazon Go app.

7 Wide selection
In addition to selling popular brands, the store stocks some exclusive own-brand items, including Amazon Meal Kits.

8 Not entirely automated
While there are no cashiers, people are still employed to stack the shelves and prepare fresh food.

9 Shop with friends
A shopper can bring up to two guests with them by scanning to let them in first, but the shopper will be charged if these guests take anything.

10 Crowd control
The roughly 167m² Seattle store can accommodate around 90 shoppers at one time. This cap is due to fire safety rather than limitations of the store's tracking technologies.



SPACE FORCE

President Trump wants one, but what actually is a 'Space Force', and how would it work?

Words by **Jonathan O'Callaghan**

NASA created this poster to promote their 'Journey to Mars' ambitions

The militarisation of space has been progressing since the dawn of spaceflight itself. NASA's formation in 1958, for example, was the result of an ongoing struggle over whether the US national space agency should be used for military or civilian purposes. Ultimately the latter won out and NASA became the pacifist scientific agency it is today. However, this hasn't stopped branches of the military in both the US and abroad from conducting their own activities in space, and recent comments from President Trump suggest the US may be looking to take this even more seriously in future. But what does it all mean? Let's find out.

"When it comes to defending America, it is not enough to merely have an American presence in space. We must have American dominance in space," President Trump announced on 18 June 2018 in a speech at the White House. "I'm hereby directing the Department of Defense and Pentagon to immediately begin the process necessary to establish a Space Force as the sixth branch of the armed forces. That's a big statement. We are going to have the Air Force, and we are going to have the Space Force – separate but equal."

"We must have American dominance in space" – President Trump

The other five US forces are the Army, the Marine Corps, the Navy, the Air Force and the Coast Guard. Yet while it might sound a bit crazy, having a separate branch of the military to handle space purposes is something that has been discussed for a long time. At the moment the US Air Force oversees almost all American military operations in space, while other branches of the military also occasionally get involved. This is through Air Force Space Command and the Space and Missile Defense Center. However, many have argued in favour of a single, centralised branch through which all military space activities could be carried out. A Space Force, if you will.

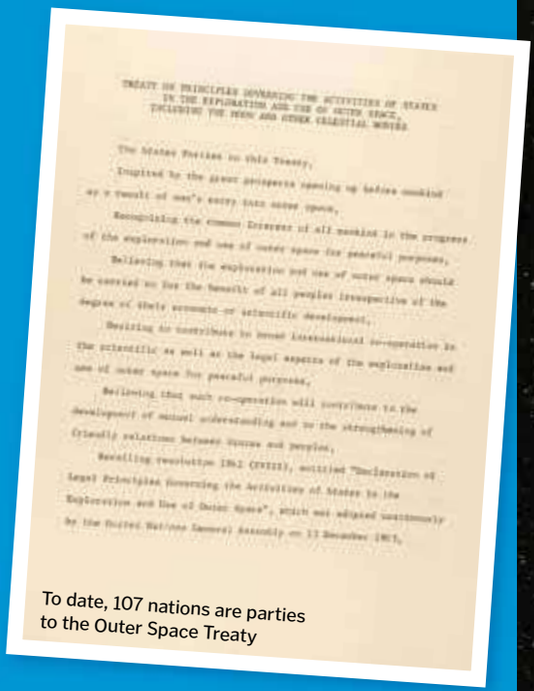
The Outer Space Treaty

The 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies – more commonly known as the Outer Space Treaty – is an international law designed to keep space free, open and fair.

At the height of the space race the goal was to ensure no country could lay claim to anything in space, like the Moon, nor claim a sector of space for their own. It also dictated that countries would be responsible for any launches from their own soil, be they government or private launches, something that's very relevant today. It also forbade the use of nuclear weapons in space and did its best to ensure space was used only for peaceful purposes. The treaty remains the foundation of our off-planet activities today.

Key principles:

- ☑ Exploring outer space should be done for the benefit of all humankind.
- ☑ Outer space is free to be explored by any country, and no nation can claim sovereignty of space at any point.
- ☑ Nuclear weapons, or other weapons of mass destruction, cannot be used in space or on the surface of other worlds.
- ☑ The Moon and other bodies must be explored for peaceful purposes only. No country can lay claim to them.
- ☑ Astronauts must be regarded as representatives of Earth.
- ☑ Each country is responsible for their own activities in space and any companies that launch from their own soil.
- ☑ Countries are also responsible for any damage they cause in space and must avoid contaminating other worlds.



To date, 107 nations are parties to the Outer Space Treaty

Other space treaties

The Rescue Agreement of 1968
Countries must assist astronauts in distress in space and help other countries recover any space debris they lose on Earth.

The Liability Convention of 1972
Countries are responsible for any damage caused by their public or private space activities and must pay compensation if necessary.

The Registration Convention of 1975
Countries must provide details to the United Nations (UN) about any objects that they have sent into orbit around Earth.

The Moon Agreement of 1979
No country can lay claim to the Moon or any other celestial bodies, and they must inform the UN of any stations built on them.

One of the major concerns about the militarisation of space is the perceived threat of other nations, such as the old enemy Russia or the new adversary that is China. General James 'Mad Dog' Mattis, US Secretary of Defense, has previously called space a "warfighting domain", with particular concerns raised about how vital space is to the military. The US Global Positioning System (GPS), for example, is imperative to keeping track of troops across the globe, and communications satellites are crucial in enabling conversations between any two locations. If an enemy nation were to try and destroy some of the satellites used for these efforts it could seriously hamper activities on the ground. But what would the Space Force do? Well, that's where things get a bit vague.

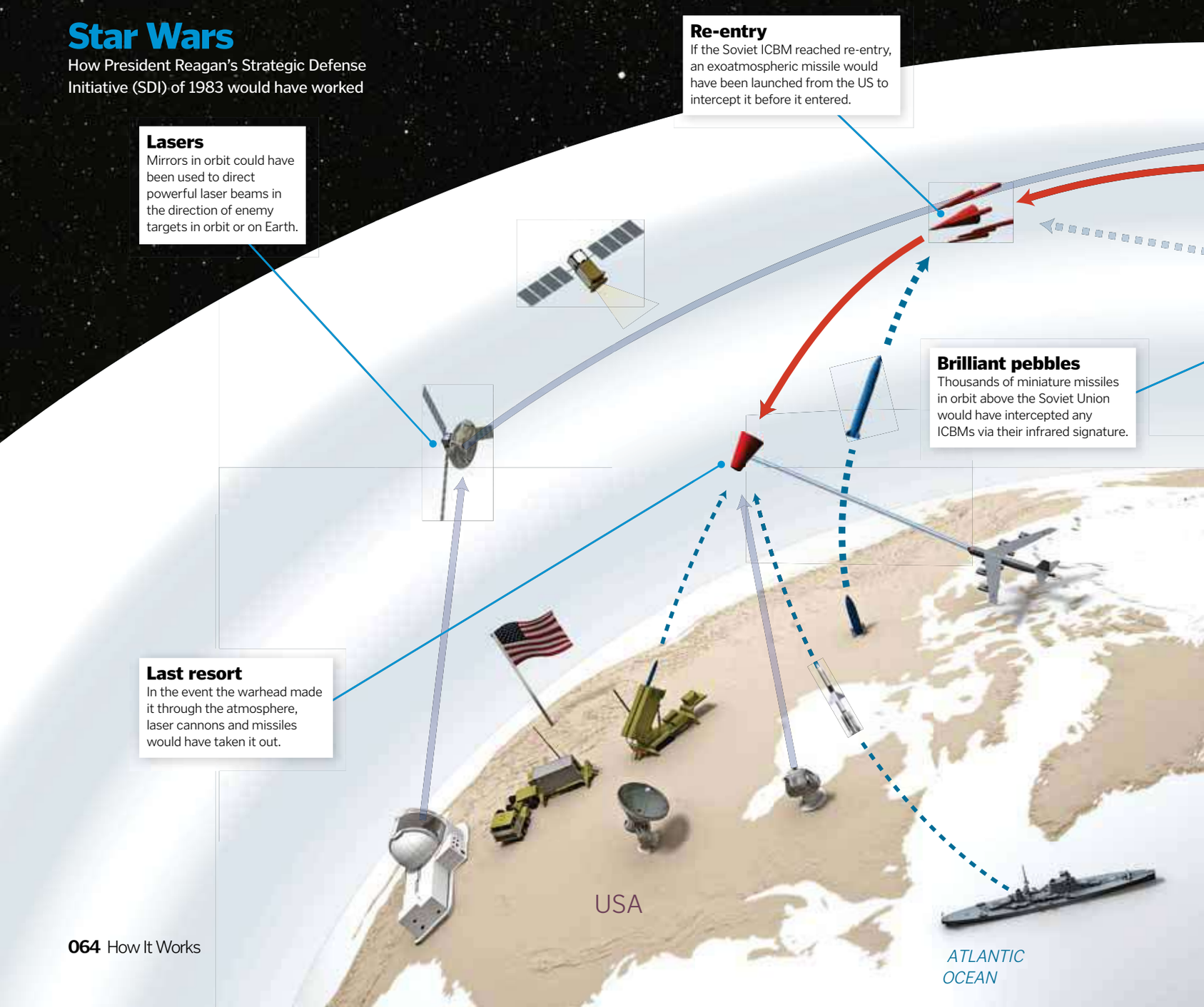
As mentioned, it would provide a more centralised branch in which all activities beyond the orbit of Earth could be incorporated, perhaps as important as the Army or Navy. Existing departments like Air Force Space Command would be taken under its wing, which already employs more than 36,000 people. By some counts there are 60 different parts of the US military involved in space, so it would provide a single command hub to control all of these. It would also enable the military to more directly deal with any threats in orbit – or beyond.

> "The US military has continued to operate in space"

There is no shortage of fears about other countries acting malevolently in space. In May 2014, a Russian satellite called Kosmos 2499 – and nicknamed Kamikaze – was rumoured to be testing out a capability to cosy up to other satellites and destroy them, although exactly how it would achieve this isn't clear. In September 2014, another Russian satellite called Luch was watched nervously as it flew close to three US and one European satellite in orbit. Some thought it could have been close enough to intercept signals, and it highlighted the growing unease surrounding space operations. In 2013, a Chinese satellite called Shiyan practised grabbing a smaller satellite with a robotic arm, something that could be used to pull other satellites out of orbit – a

Star Wars

How President Reagan's Strategic Defense Initiative (SDI) of 1983 would have worked



development that only serves to escalate growing concerns.

These fears have been around in one form or another for quite a while. In the 1980s, during the Cold War, President Ronald Reagan proposed his Strategic Defense Initiative (SDI), a bold idea to create a missile defence system with satellites that could shoot down incoming nuclear missiles from the Soviet Union.

Incorporating advanced technologies such as lasers and hypervelocity railguns, the proposal was widely ridiculed as a waste of money – not least because its end goal was deemed impossible – and was given the unwanted moniker of 'Star Wars'.

Before and since then, however, the US military has continued to operate in space, often keeping their activities shrouded in

President Lyndon B Johnson (right) shakes hands with Soviet ambassador Anatoly Dobrynin after the Outer Space Treaty came into effect on 10 October 1967

Brilliant Eyes
A tracking system known as Brilliant Eyes (later Space and Missile Tracking System) would have monitored any objects.

Detection
Satellites in orbit would be used to detect the launch of a nuclear warhead from the Soviet Union.

The system
The entire SDI system would have aimed to prevent a Soviet rocket reaching the US at several key stages.

Surface-to-air
Missiles fired from the ground would intercept intercontinental ballistic missiles (ICBMs) before they reached space.

USSR

Military satellite uses and vulnerabilities

Communications
Often found in geostationary orbits almost 36,000 kilometres high, these enable militaries to command forces in real time anywhere around the world.

Early warning systems
These satellites closely monitor launch sites around the world and send out alerts if any missile launches take place.

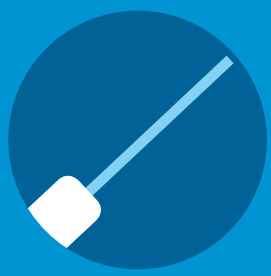
Reconnaissance
These lower-orbiting satellites take images for surveillance purposes, meaning high-resolution pictures of sites of interest can be snapped.

Positioning
Position equipment such as GPS allows the position of a person or device to be pinpointed to within just a metre or so.

Blocking
On the ground, people can use jammers to try and block the signals from satellites, such as those used for navigation.

Shooting down
On rare occasions a satellite could be shot down to prevent it operating. China conducted such an anti-satellite test in 2007.

Nuclear weapons
High-altitude nuclear tests could in theory destroy satellites in low-Earth orbit due to the electromagnetic pulse (EMP) they create.



Direct energy weapons
Lasers on the ground could be used to push a satellite out of orbit or render it inoperable by destroying some of its electronics.

Harpoons and nets
Smaller satellites employing a net, harpoon or other such tech could be used to de-orbit other larger satellites and send them into the atmosphere.

The role of a Space Force could evolve in line with our future spacefaring ambitions

While it may sound like something out of a sci-fi, a Space Force is unlikely to be as exciting as its name might suggest

secrecy. The mysterious X-37B project, for example, has seen the US Air Force repeatedly test an uncrewed mini-shuttle over the last decade, one that can be sent to orbit and then return to Earth. While they insist it is not a weapon, other countries have raised concerns this is a prototype for a space fighter, one that can actively engage in combat in orbit. A true space war, if you will.

All of this means that Trump's comments are just the latest in a long history the US military has had with space. The benefits of actually creating a Space Force are questionable though. It would add a potentially unnecessary layer of bureaucracy to space activities and undoubtedly cost large sums of money to set up. With Air Force Space Command seemingly doing a decent job at the moment, you'd be right to question why a Space Force is needed at all. Even so, proponents argue it would properly recognise space as an increasingly volatile battlefield.

With so many resources invested in orbit, and more to come in the future, shouldn't space be regarded as an arena equal in importance to the land, air and sea? Perhaps

by unifying space activities, which are spread across the whole US military, the country will be better placed to meet any threats.

There are plenty of hurdles to this actually happening though. First, there is the legal aspect, mainly thanks to the 1967 Outer Space Treaty. Although it does not explicitly forbid military activities in space, it does state that its signatories – which include the US, Russia and China – must explore space for peaceful purposes. Then there is the fact that space itself falls under the remit of international law, so if a country wanted to start shooting weapons in space, while not outlawed by the Outer Space Treaty, it would likely fall foul of other international regulations.

> *"The growing unease isn't going anywhere"*

There's also the political aspect. If Trump wants to set up a Space Force he will need the approval of Congress, and at the time of writing they are not particularly keen on the idea. In July 2018, the House of Representatives and the Senate reached a deal on defence spending for the US in 2019, and notably absent was any mention of a Space Force. They did recommend developing "a space warfighting policy", but they did not directly recommend setting up a new branch of the military. The legislation still has to be voted on and signed by Trump though, so the situation could still change.

The biggest take-home here should be that a Space Force is a manifestation of the growing presence of the military in space. It is not a new idea – Obama recognised space as a zone for military activities – nor is it radical in what it proposes. The more pressing concern should not be that this is being considered at all, but that it needs to be considered in the first place. The name itself elicits images of a bygone era of Cold War tensions, and there are reasonable fears the creation of a Space Force could increase the already fraught tensions between the US, China and Russia.

Trump's idea may not become a reality, but the growing unease over what's orbiting thousands of miles per hour above our heads isn't going anywhere soon.

In 2008 the US Navy launched an SM-3 missile to destroy a decommissioned reconnaissance satellite

Parker Solar Probe

How this amazing mission will touch the Sun – and survive

Launched aboard a Delta IV Heavy rocket on 12 August 2018, NASA's Parker Solar Probe will get more than seven-times closer to the Sun than any other spacecraft in history. The probe will make 24 orbits of the Sun on a journey that will almost literally touch its atmosphere and study our Solar System's star in unprecedented detail.

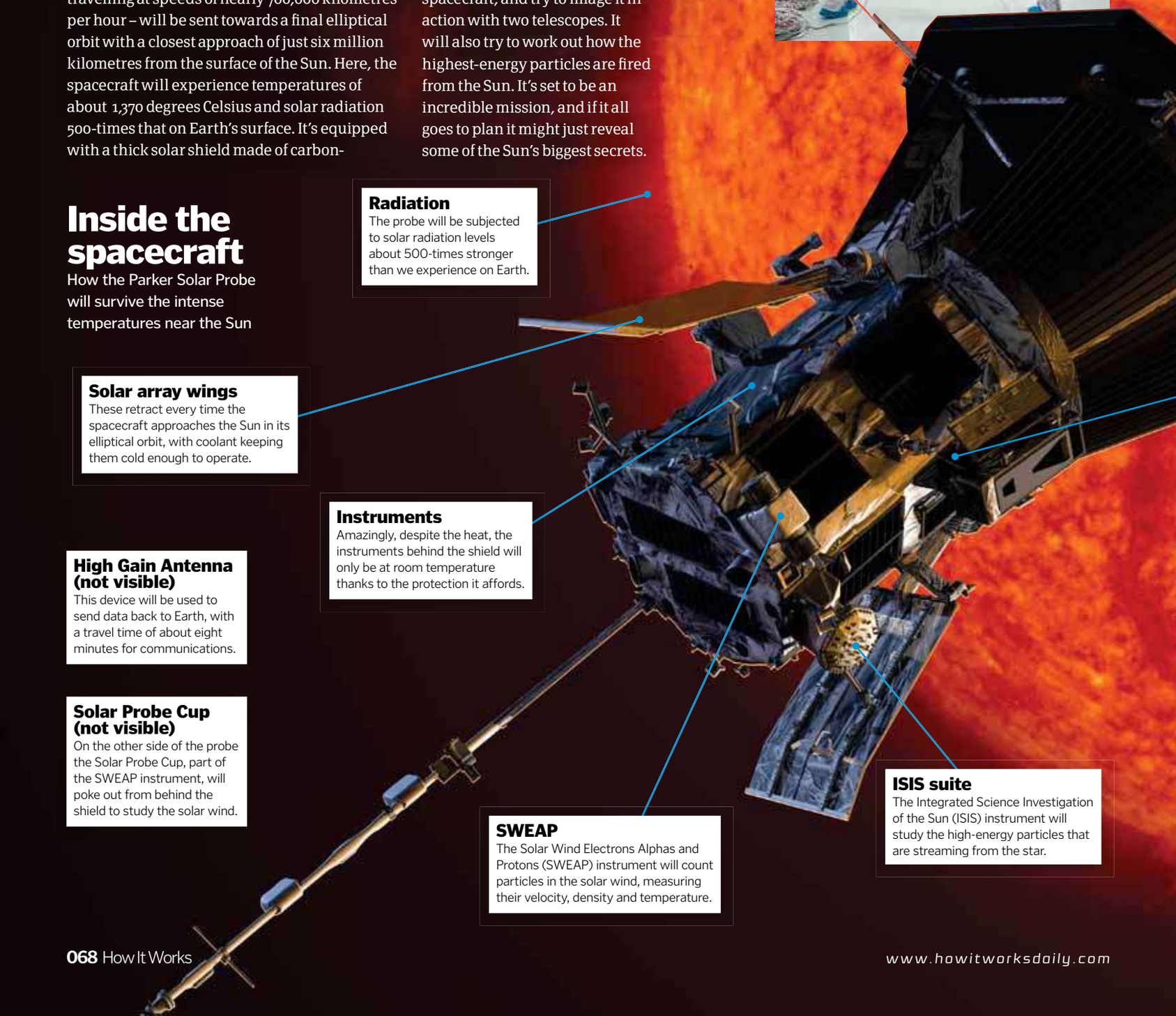
The spacecraft has been sent on a long, spiralling journey that will slowly take it closer and closer to the Sun. Using seven flybys of Venus over seven years, the spacecraft – travelling at speeds of nearly 700,000 kilometres per hour – will be sent towards a final elliptical orbit with a closest approach of just six million kilometres from the surface of the Sun. Here, the spacecraft will experience temperatures of about 1,370 degrees Celsius and solar radiation 500-times that on Earth's surface. It's equipped with a thick solar shield made of carbon-composite to withstand these conditions, keeping its instruments operating at around room temperature.

If the mission is successful, the payoff could be huge. At these distances, the Parker Solar Probe will be able to study the Sun like never before. It will fly through the Sun's corona – its outer atmosphere – to study how it transfers heat. It will also watch as solar wind speeds past the spacecraft, and try to image it in action with two telescopes. It will also try to work out how the highest-energy particles are fired from the Sun. It's set to be an incredible mission, and if it all goes to plan it might just reveal some of the Sun's biggest secrets.

The spacecraft has a complex array of instruments onboard

Inside the spacecraft

How the Parker Solar Probe will survive the intense temperatures near the Sun



Radiation
The probe will be subjected to solar radiation levels about 500-times stronger than we experience on Earth.

Solar array wings
These retract every time the spacecraft approaches the Sun in its elliptical orbit, with coolant keeping them cold enough to operate.

Instruments
Amazingly, despite the heat, the instruments behind the shield will only be at room temperature thanks to the protection it affords.

High Gain Antenna (not visible)
This device will be used to send data back to Earth, with a travel time of about eight minutes for communications.

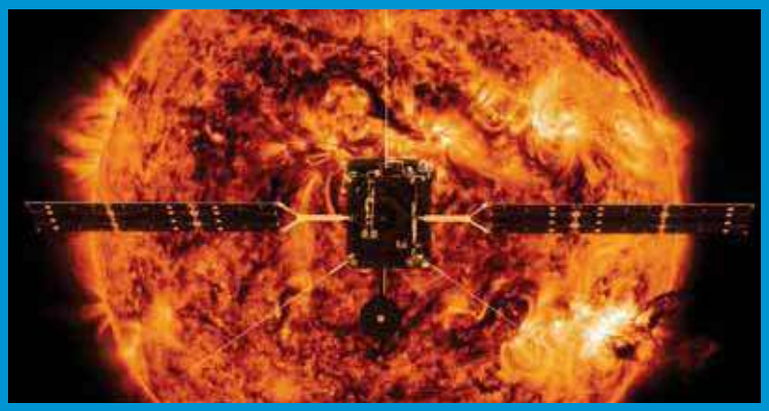
Solar Probe Cup (not visible)
On the other side of the probe the Solar Probe Cup, part of the SWEAP instrument, will poke out from behind the shield to study the solar wind.

SWEAP
The Solar Wind Electrons Alphas and Protons (SWEAP) instrument will count particles in the solar wind, measuring their velocity, density and temperature.

ISIS suite
The Integrated Science Investigation of the Sun (ISIS) instrument will study the high-energy particles that are streaming from the star.

A fiery companion

Scheduled for launch in 2020, the Solar Orbiter mission from the European Space Agency (ESA) will work in tandem with the Parker Solar Probe to give us even more information about the Sun. Although it won't come as close, approaching our star at just 43 million kilometres, it will attempt to tilt its orbit and become the first spacecraft to ever take direct images of the Sun's poles. Like the Parker Solar Probe, it will study the Sun's outer atmosphere, as well as the solar wind, and thanks to its unique orbit, it could tell us more about how the Sun's magnetic fields behave at its poles. The mission is expected to last seven years, with the possibility of it being extended further after that to get an even better look at the poles.



ESA's Solar Orbiter won't get as close to the Sun, but it will still be an impressive mission

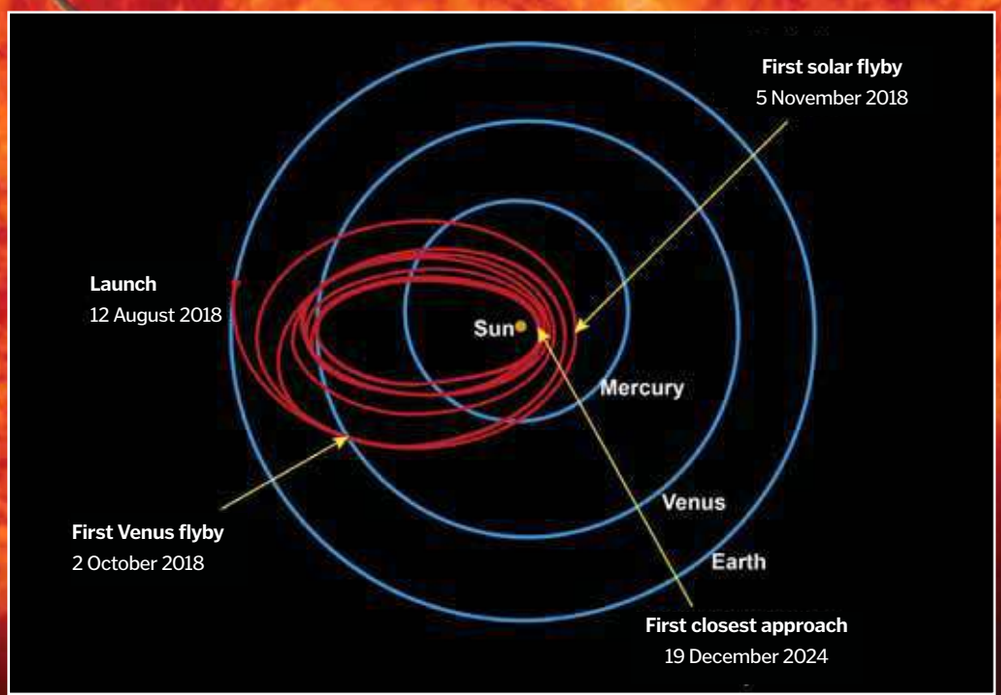
FIELDS
The Electromagnetic Fields Investigation (FIELDS) will attempt to make direct measurements of the Sun's electric and magnetic fields.

Solar shield
An 11.43cm-thick carbon-composite shield at the front of the probe will withstand temperatures of about 1,370°C.

WISPR
The Wide-field Imager for Solar Probe (WISPR) telescopes will try to image the effects of the solar wind and the Sun's atmosphere.

The Parker Solar Probe was tested in a mock space environment for eight weeks

"If the mission is successful, the payoff could be huge"



Sending names to the Sun

Up until April 2018, NASA invited people from around the world to submit their names to be included on a microchip on the Parker Solar Probe. A total of 1,137,202 people took part, including celebrities like *Star Trek*'s William Shatner. In May 2018, a special memory card containing all of the names was installed on the spacecraft along with a plaque honouring heliophysicist Eugene Parker, for whom the mission is named. Some photos of Parker are also included on the memory card, along with his famous 1958 scientific paper that first described solar wind.

A memory chip containing over 1.1 million names is included along with a plaque on the spacecraft

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What is interferometry?

How this clever technique can create a telescope over half the size of Earth

When it comes to telescopes, the bigger the better. A larger primary mirror or objective lens (in optical telescopes) or antenna (in radio telescopes) collects more light or radio waves, resulting in more detailed images. But building massive telescopes is incredibly expensive, and beyond a certain size it simply becomes impractical.

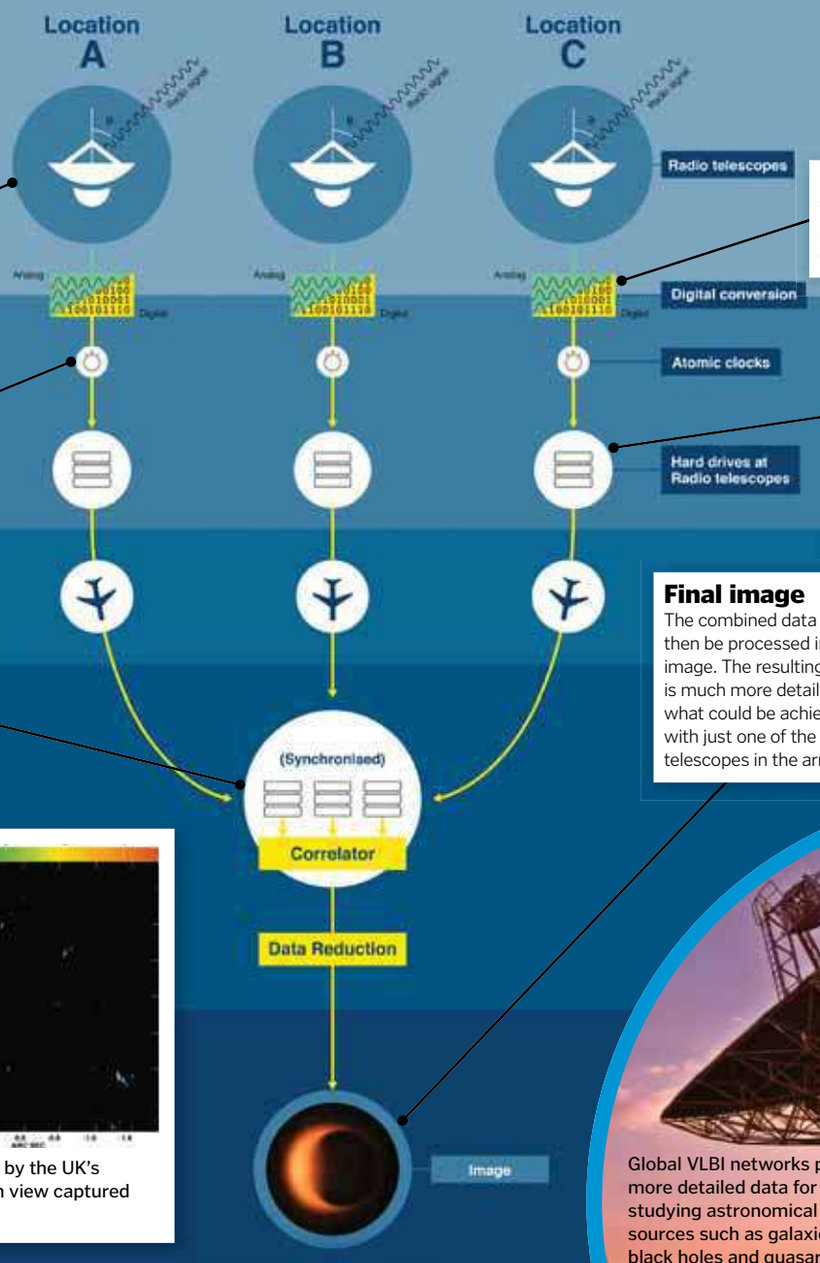
To be able to view the Moon in enough detail to spot the lunar landers, for example, you would need an optical telescope with a 60-metre-diameter mirror. To put this in context, the largest optical telescope on Earth – the Gran Telescopio Canarias – has a 10.4-metre mirror, and the orbiting Hubble telescope's is only 2.4 metres wide.

A technique called interferometry can overcome this problem. If you can combine the light collected by two telescopes positioned 60 metres apart, you will see the same amount of detail as a single 60-metre-wide telescope. In optical interferometry the telescopes must be physically connected to combine the data, which can limit how far apart they can be placed. With radio interferometry, however, the signals can be combined remotely at a later date, so the telescopes themselves can be placed anywhere in the world.

Very long baseline interferometry (VLBI) uses networks of linked radio telescopes positioned very far apart – often across entire continents or hemispheres, or even in orbit – in order to view the universe in much greater detail. One of the largest VLBI systems is the Very Long Baseline Array (VLBA), which consists of ten radio telescopes in Hawaii, across the mainland US, and the Virgin Islands. This system can provide the same level of detail as a single telescope over 8,600 kilometres wide!

How VLBI works

Interferometry makes radio telescopes greater than the sum of their parts



Radio telescopes
The linked antennae collect radio waves from a specific target in the universe. They are not restricted by physical connections so can be positioned anywhere in the world.

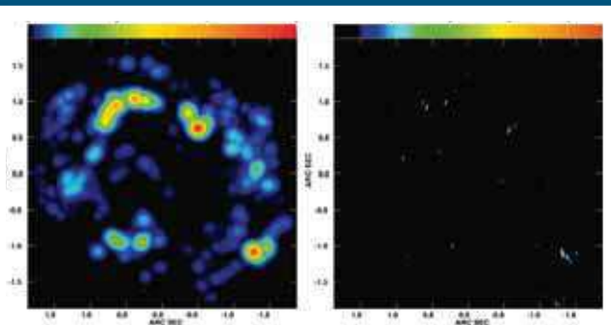
Digitising the signals
The radio antennae collect analogue signals, which are then converted into digital data.

Atomic clocks
Each telescope in the array has an atomic clock, which provides ultra-precise time measurements of each observation.

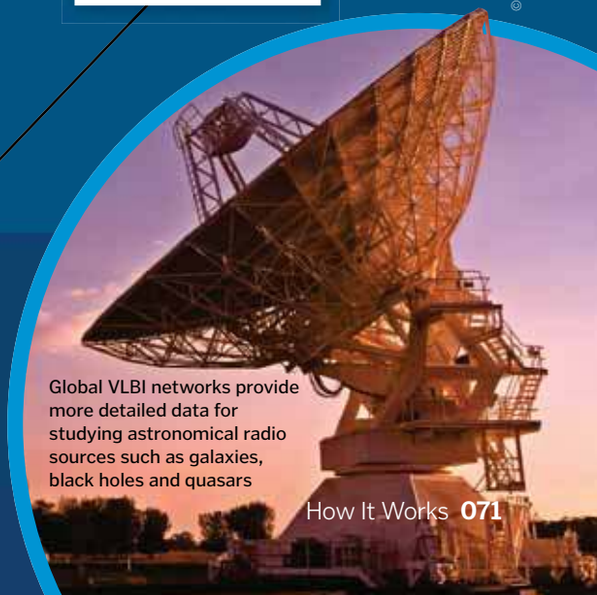
Hard drives
The digitised radio data and the time stamps from the atomic clocks are stored on hard drives at each telescope site.

Combining the data
The hard drives from each telescope are shipped to a specific location to be synchronised. However, in some networks it is now possible to combine the telescope data in real time with gigabit-per-second fibre-optic connections, known as e-VLBI.

Final image
The combined data can then be processed into an image. The resulting image is much more detailed than what could be achieved with just one of the radio telescopes in the array.



The radio emissions of an expanding gas shell seen by the UK's MERLIN array (left), and the much higher-resolution view captured by the European VLBI Network (right)



Global VLBI networks provide more detailed data for studying astronomical radio sources such as galaxies, black holes and quasars

MYSTERIES OF THE MAYA

Deep in the rainforests of Mexico lie the ruins of an ancient civilisation

Words by **Jodie Tyley**

Mesoamerica was home to some of the most iconic civilisations of the world, each with its own unique achievements. The Aztecs had their elite warriors, the Incas their engineering marvels, and the Maya made apocalyptic predictions. However, the Maya were responsible for much more than the 2012 Doomsday headlines. Accomplished mathematicians, artists, astronomers and architects, they even developed the first writing system in the pre-Columbian Americas.

The Maya ruled much of Mexico and northern Central America, pre-dating the Aztec and Inca empires. Unlike their successors, the Maya did not have a single ruler or centralised authority, their realm instead comprising a collection of city states ruled independently by kings but united in their beliefs and culture. Religion was fiercely important, and they built towering temples to worship their pantheon of gods – there were as many as 250! It was these temples that led 20th-century archaeologists to believe these settlements were "vacant ceremonial centres", inhabited only by priests. They were a peaceful community of forest dwellers – or so those who studied their ways thought.

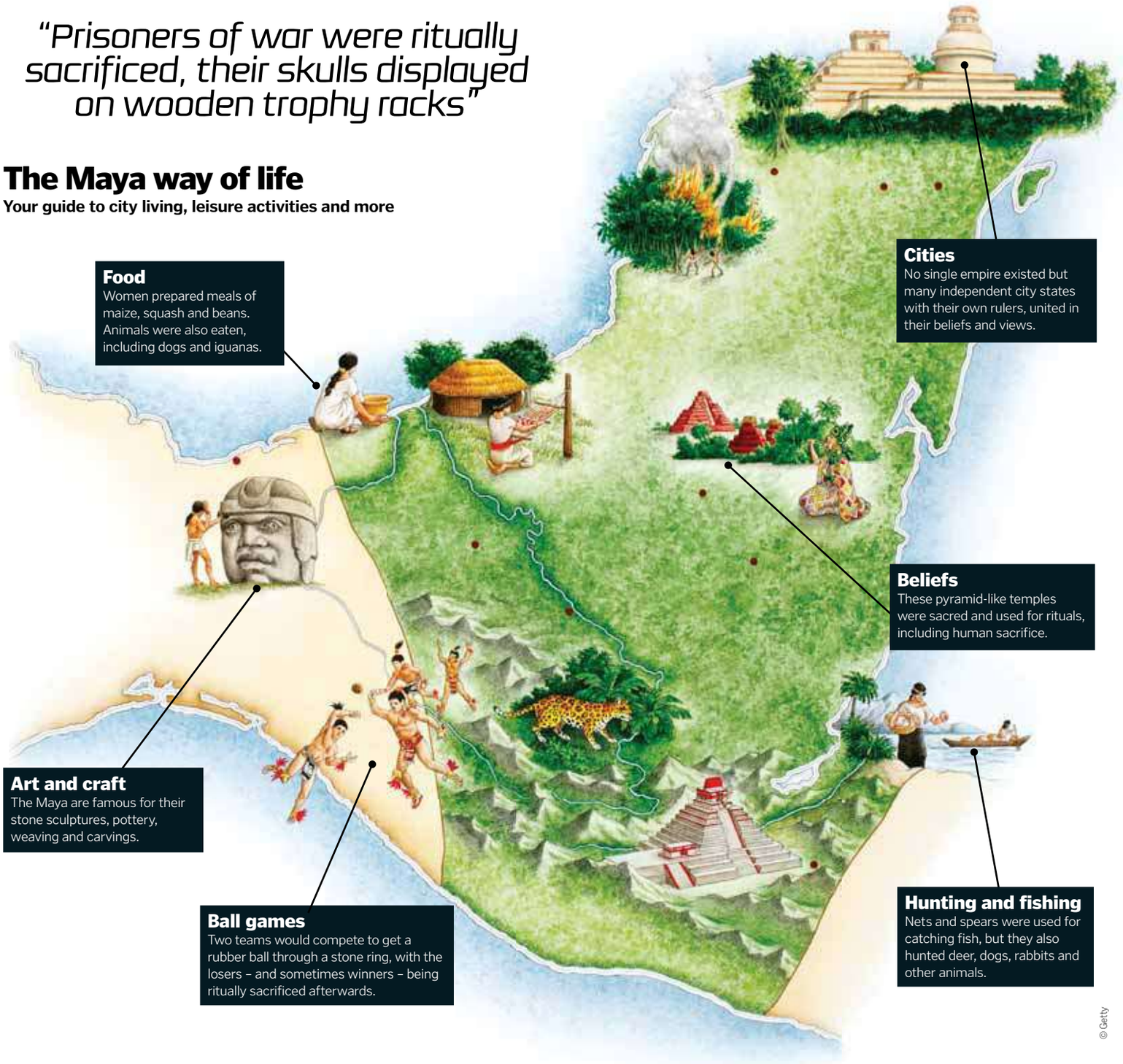
In reality, war was not uncommon between these Maya cities, often sparked by rivalry over trade and territory, and the victors would leave with more than just status. Prisoners of war were ritually sacrificed, their skulls displayed on wooden trophy racks called tzompantli. The Maya believed human sacrifice would appease and nourish the gods, who had spilled their own blood to create humankind. Even the elite mutilated themselves, usually with stingray spines or blades made from obsidian.

One gruesome carving depicts King Shield Jaguar II holding a flaming torch over his wife, Lady Xook, who is pulling a barbed rope across

"Prisoners of war were ritually sacrificed, their skulls displayed on wooden trophy racks"

The Maya way of life

Your guide to city living, leisure activities and more



Food
Women prepared meals of maize, squash and beans. Animals were also eaten, including dogs and iguanas.

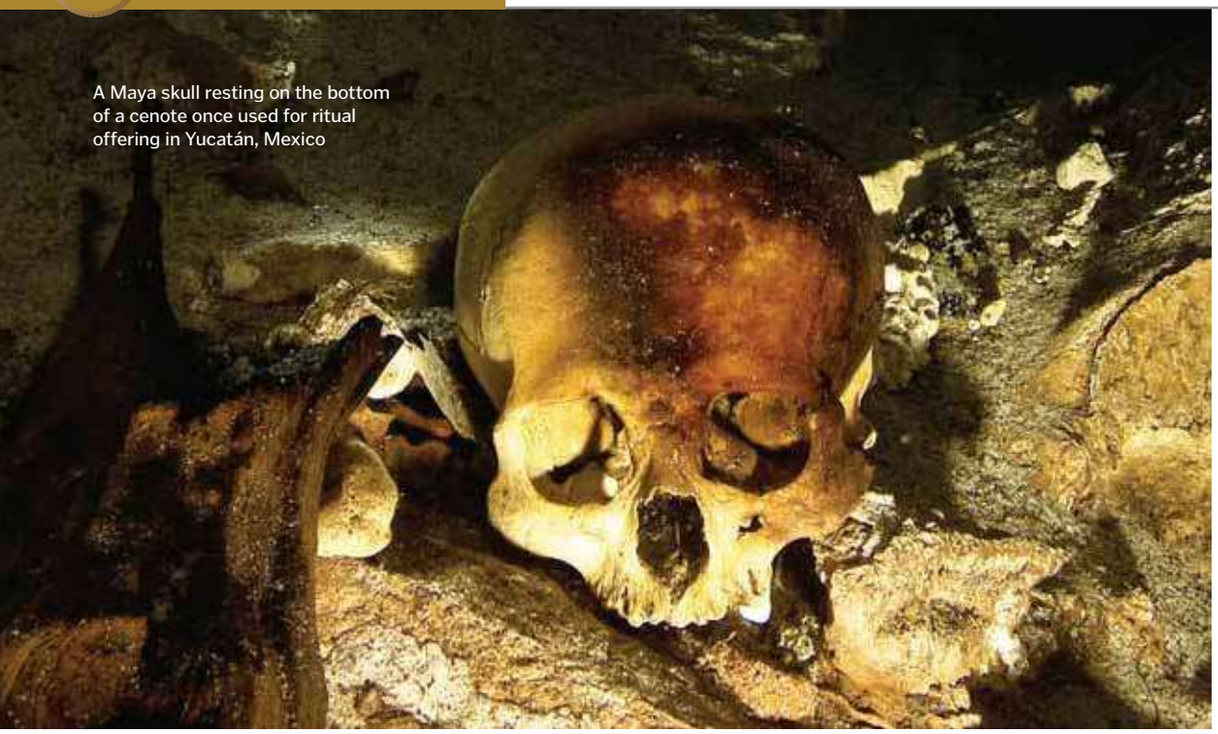
Cities
No single empire existed but many independent city states with their own rulers, united in their beliefs and views.

Beliefs
These pyramid-like temples were sacred and used for rituals, including human sacrifice.

Art and craft
The Maya are famous for their stone sculptures, pottery, weaving and carvings.

Ball games
Two teams would compete to get a rubber ball through a stone ring, with the losers – and sometimes winners – being ritually sacrificed afterwards.

Hunting and fishing
Nets and spears were used for catching fish, but they also hunted deer, dogs, rabbits and other animals.



A Maya skull resting on the bottom of a cenote once used for ritual offering in Yucatán, Mexico

This limestone carving shows Lady Xook pulling a thorny rope through her tongue during a ritual

her tongue. These gruesome rituals were thought to be a way of communicating with the supernatural world for guidance. Once blood was spilled onto cloth, it would be burned and the 'vision serpent' would appear in the smoke – a conduit for the gods or spirits of royal ancestors from the Underworld.

The Maya saw the universe as a great Tree of Life. The Middleworld (Earth) was the trunk, the Underworld was the roots and the Upperworld was the branches. Both the Upper and Underworld were feared and revered – they were where deities and spirits resided – but parts of the Middleworld could tap into these supernatural spheres too. Caves and cenotes (water-filled sinkholes) were considered portals to the Underworld. The word 'cenote' actually originates from the Maya word for 'sacred well', but rather than tossing in a few coins and making a wish, they made offerings in the form of human bodies, ceramics, sculptures and jewels. Their only wish was that this would be enough to keep the gods happy. Incurring their wrath would unleash famine, disease and other horrors upon their population.

On a practical level, these cenotes provided a fresh water supply for farming, which is another reason why many Maya cities were built in close proximity to them. For example, the temple of El Castillo in Chichén Itzá is near to cenotes in the north, east, south and west, and archaeologists believe an entrance to yet another subterranean sinkhole lies underneath the pyramid. This suggests that the Maya chose this site because of its religious significance.

The design and orientation of temples and other buildings were also influenced by the night sky – considered to be the Upperworld. Like much older civilisations, the Maya were keen astronomers. They thought of the sky as a double-headed serpent that swallowed the Sun and the Moon in the west, only for them to reappear in the east. The fact their words for snake and sky were very similar was probably no coincidence. Astronomy was used to plan the Maya ceremonial calendar, in particular the position of Venus. This bright light captured their attention – they saw it as an omen of war and rulers would even organise military campaigns according to the planet's movements.

Observations of the skies also informed farmers when to plant and harvest their crops. The Maya relied on a diet of mostly maize, squash and beans to feed their large population, but the challenging terrain of the rainforest wasn't ideal for agriculture. Instead, they developed an ingenious solution. Canals were built between wetlands to divert the water to where it was needed. They also created raised beds alongside these canals so the crops were safe from the waterlogged soil. Maize was hugely important to the Maya – it didn't just nourish them, it gave them life. According to their creation story, the gods made humans from ground maize and blood.

The majority of the Maya were farmers – men cultivated the crops and women prepared the meals – and they were the lowest in society's pecking order. Next were the merchants and

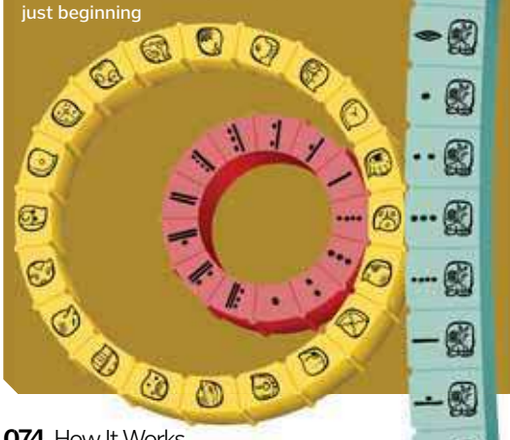
The wheels of time

The Maya used three calendars simultaneously: the Tzolk'in, the Haab' and the Long Count. The Tzolk'in lasts for 260 days and has a cycle of 20 periods of 13 days. The days are numbered from one to 13, and they each have a name represented by a symbol (glyph). This calendar was used to schedule religious ceremonies.

The Haab' is a 365-day calendar divided into 18 months of 20 days each, and one month of five 'unlucky' days. This measures the time it takes for the Earth to orbit the Sun, but it doesn't account for the extra quarter-day the Earth needs to complete its journey (which is why we have leap years). The Haab' has an outer ring of glyphs that symbolise the 19 months, while dots and bars indicate the days.

Meanwhile, the Long Count tracks what the Maya called the 'universal cycle' of 2,880,000 days (around 7,885 solar years). The Maya believed the universe is destroyed and re-created every cycle. One of the cycles ended during the 2012 winter solstice, which triggered the prediction that the world would end on 21 December 2012.

The Maya calendar did not cease to exist in 2012 – another Long Count period was just beginning



Maya milestones

2600 BCE
The Maya begin to settle in the Yucatán area of Mexico.

700 BCE
Writing develops in Mesoamerica, using symbols called glyphs.

300 BCE
Maya society adopts a hierarchy dominated by nobles and kings.

250 CE
The Classic Period begins, when the Maya reached the peak of their powers.

900 CE
The collapse of the southern lowland cities signifies the end of the Classic Period.

1200
Northern cities begin to be abandoned, including Chichén Itzá.

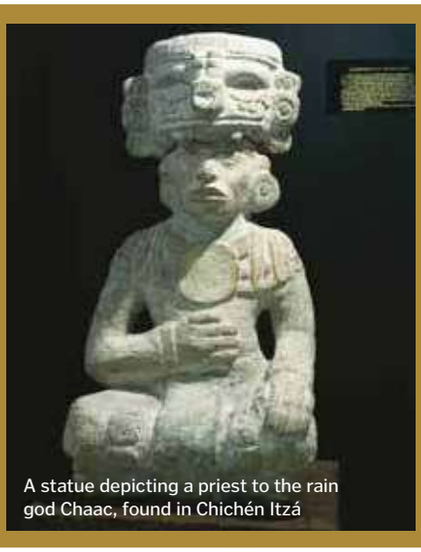
1511
Spanish conquistadors arrive in Yucatán, bringing diseases that would kill much of the native population.

Mid-1500s
Spanish cities were established in the Maya region. The last Maya city remained independent until 1697.

The end of the Maya

By the time of the Spanish conquest in the early 1500s, many Maya cities were already in ruin. They had been abandoned hundreds of years before, leaving experts clueless as to why. One theory is that warfare tore them apart, and a recent gruesome discovery supports this. The skeletons of 31 assassinated royals and nobles were unearthed in the ruins of the Maya city Cancuén. The area was abandoned soon after, as were other nearby cities.

Others believe collapsing trade routes, diseases or severe droughts were to blame, and recent evidence suggests the latter certainly dealt a crippling blow. Scientists have found that rainfall plummeted by half during the period of the Maya's demise, sometimes by as much as 70 per cent. This drought would have turned land to desert, evaporating water from lakes and dooming crops to dust. Perhaps as a sign of their desperation, masks of the Maya rain god Chaac can be found among the ruins. The Classic era of the Maya had come to an end, but some major cities like Chichén Itzá continued to thrive until the Spanish arrived on their shores.



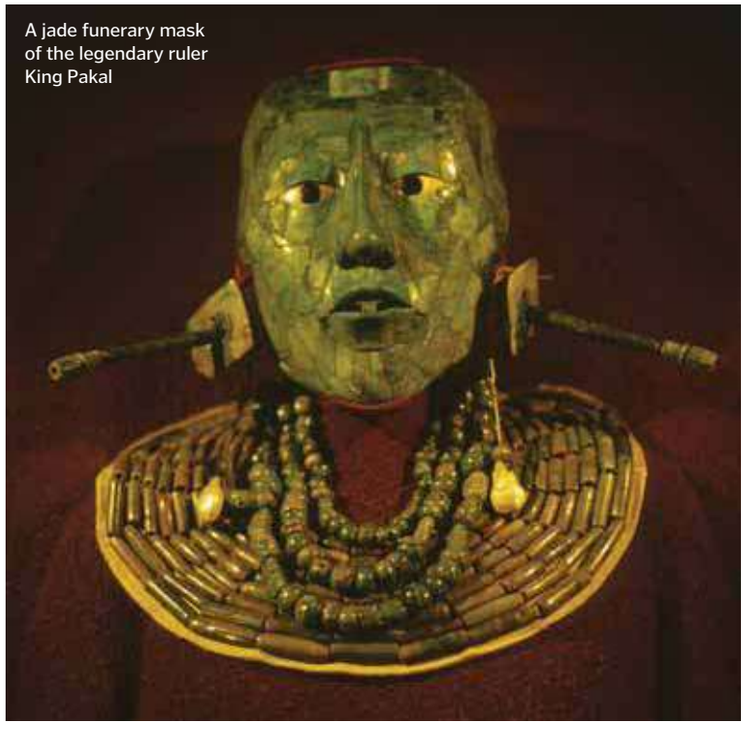
A statue depicting a priest to the rain god Chaac, found in Chichén Itzá

artisans, who traded goods with other city states and produced art to give thanks to the gods. Then came priests – the keepers of knowledge. They recorded key events using their own writing system of hieroglyphics, used mathematics to calculate the time and movement of the planets, and performed ceremonial rituals. The only people more important than priests were the nobles and the king, who had complete power over their city. They occupied enormous palaces – one was the size of several football pitches – and were thought to become gods after death.

Clearly the Maya way of life heavily revolved around the supernatural, but that didn't stop them from being a little superficial too. In Maya society an elongated head shape was all the rage, so parents would flatten their babies' soft skulls with wooden boards to create the desired effect. It's thought that this beauty trend may have been inspired by a beloved maize god whose head vaguely resembled a husk of corn. Kernels may have also inspired the fashion for filing teeth into points. The wealthy would have holes carved into their enamel to hold precious stones, such as jade. This material was valuable to the Maya because it was associated with water and the colour of the maize plant. Ear, lip and nose piercings were also popular, while some brave Maya opted to have tattoos, which were carved into the skin. Plenty of jade jewellery and bright body paint completed the look.

The Maya thrived from 250 to 900 CE, what historians call the Classic Period. But then something happened that triggered entire cities to be abandoned. What exactly caused this is still debated – deforestation, drought, wars – and speculation is rife. Some communities survived but by the 11th century the Maya were past the peak of their powers. When Spanish conquistadors arrived in the mid-1500s they were eventually overpowered. Bows, arrows and swords made of obsidian were no match for modern technology. The Spanish were armed with iron, steel, gunpowder and carried with them foreign diseases. The latter proved fatal for the majority of the remaining Maya population. Their cities were left in ruins and their written records were destroyed – only four books (codices) remain today. Yet despite the odds, archaeologists are constantly making new discoveries, and we know substantially more than we did even a few decades ago. There could be more secrets yet to be revealed.

A depiction of a Maya maize god, with elongated head and a headdress resembling maize fibres

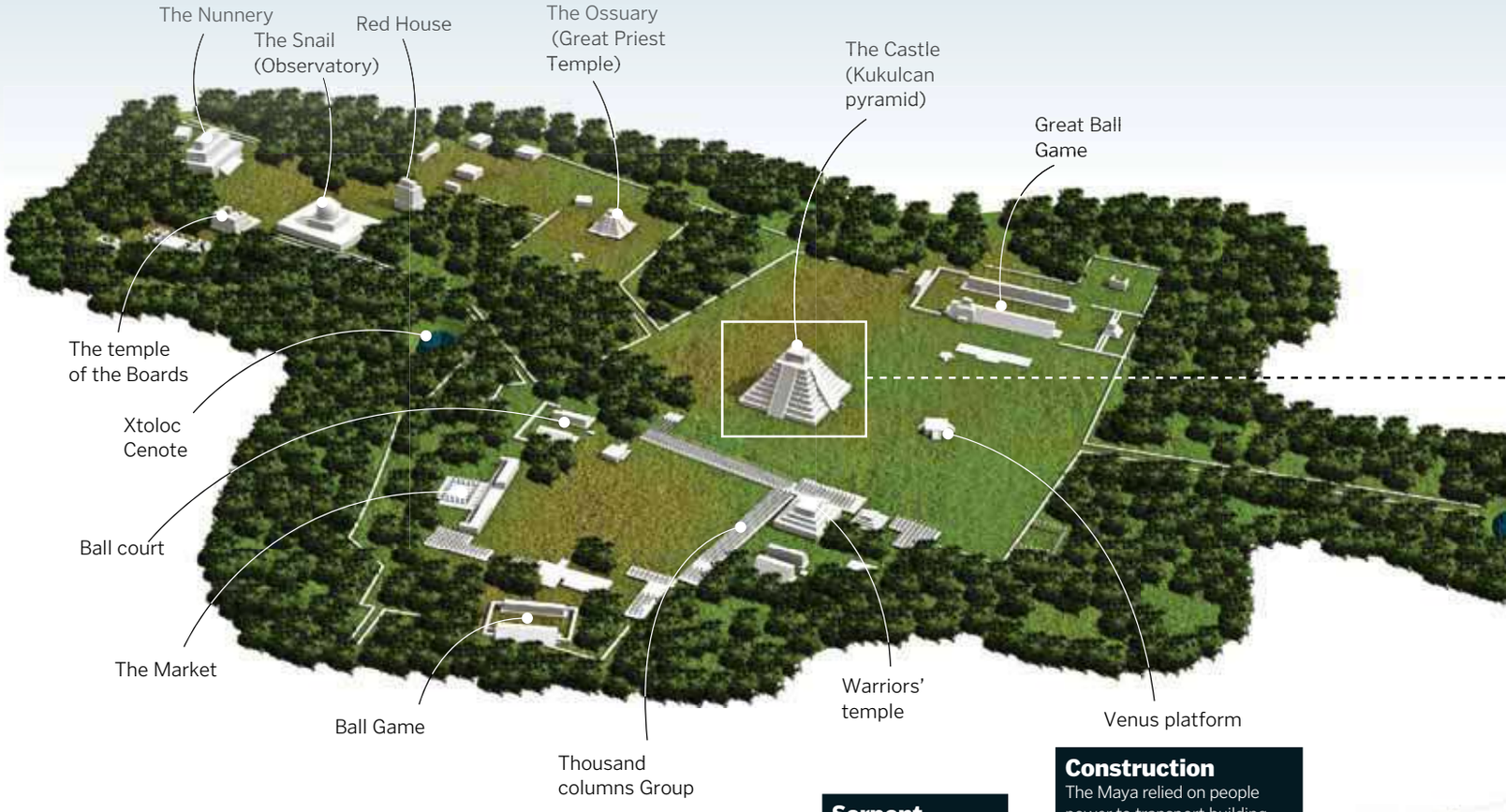


A jade funerary mask of the legendary ruler King Pakal

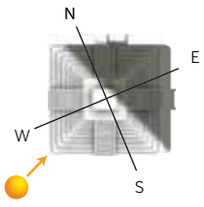
"In Maya society an elongated head shape was all the rage"

Chichén Itzá

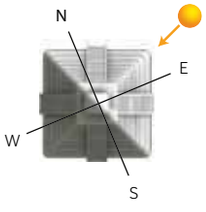
This sacred site in Yucatán is one of the New Seven Wonders of the World



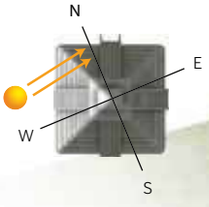
Winter solstice
21st December
(day with least sunlight in the year)



Summer solstice
21st June
(day with most sunlight in the year)



Equinox
21st March and 21st December
(days when the hours of sunlight equal the hours of darkness)



Construction
The Maya relied on people power to transport building materials. They would roll heavy stones on logs.

Serpent sculptures
Two snake-head sculptures flank the north staircase, believed to represent the god Kukulkan.

"Caves and cenotes were considered portals to the Underworld"

A spectacle of light
During the spring and autumn equinoxes, the rising and setting of the Sun casts shadows on the corner of the pyramid, leaving a sliver of the steps illuminated to create the illusion of a giant serpent.

Bird calls
If you walk towards the north stairs and clap, the echoes sound like the Mexican quetzal bird, a spiritually significant animal in Maya culture.

Write like a Maya

Maya words and sounds were represented by symbols called glyphs. There were around 700 glyphs, and they were used to record things like rituals, astronomy and events on stone slabs (stelae) and books (codices) made from soft inner bark.

Temple to the snake god

Built between the 9th and 12th centuries, El Castillo is the most famous structure of Chichén Itzá. It was dedicated to the serpent god Kukulkan and sacred rituals were performed inside the temple.

Sacred cenote

A calendar of stone

There are 91 steps on each of the pyramid's four sides. This, including the temple platform at the top, equals 365 – one for each day of the year.

Counting the months

A series of platforms on each of the pyramid's four sides total 18. There are 18 months of 20 days in the Maya calendar, and one month of only five days.

52ft

Hidden pyramids

Two older pyramids are concealed within. The second substructure is situated near a cenote. The Maya may have chosen this location on purpose, seeing it as an entrance to the Underworld.

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The explosive wreck beneath the Thames

WWII ship the SS Richard Montgomery's cargo could blow up at any moment

If you walk along the banks of the River Thames in Sheerness, Kent, you can see three ship's masts sticking out from the water. At first glance they look harmless, just a rusting relic of a disaster from days past, but look closer and you'll see signs warning of the danger beneath.

The masts belong to the SS Richard Montgomery, a US Liberty ship used during World War Two. With a hold stocked full of munitions, it arrived in the Thames Estuary in August 1944, but severe weather caused it to drag its anchor and fill with water. As the tide receded the ship was left stranded on the sand bank, and its hull soon began to buckle and crack under the weight of the cargo. A salvage operation was quickly launched, but in September 1944 this had to be abandoned when the ship finally broke in two and sank. Half of the cargo had successfully been removed, but the rest – an estimated 1,400 tons of munitions – is still lying on the riverbed today. If it detonates, it could send a catastrophic tsunami up the Thames, destroying everything in its path.

One of the biggest risks of detonation is the collapse of the remaining wreckage, so the UK's Maritime and Coastguard Agency conducts an annual survey to monitor its condition. Recent findings show that the wreck is indeed slowly deteriorating, but as removing the ship's cargo is likely to be a complicated and dangerous mission, it is safer to leave it alone for now.

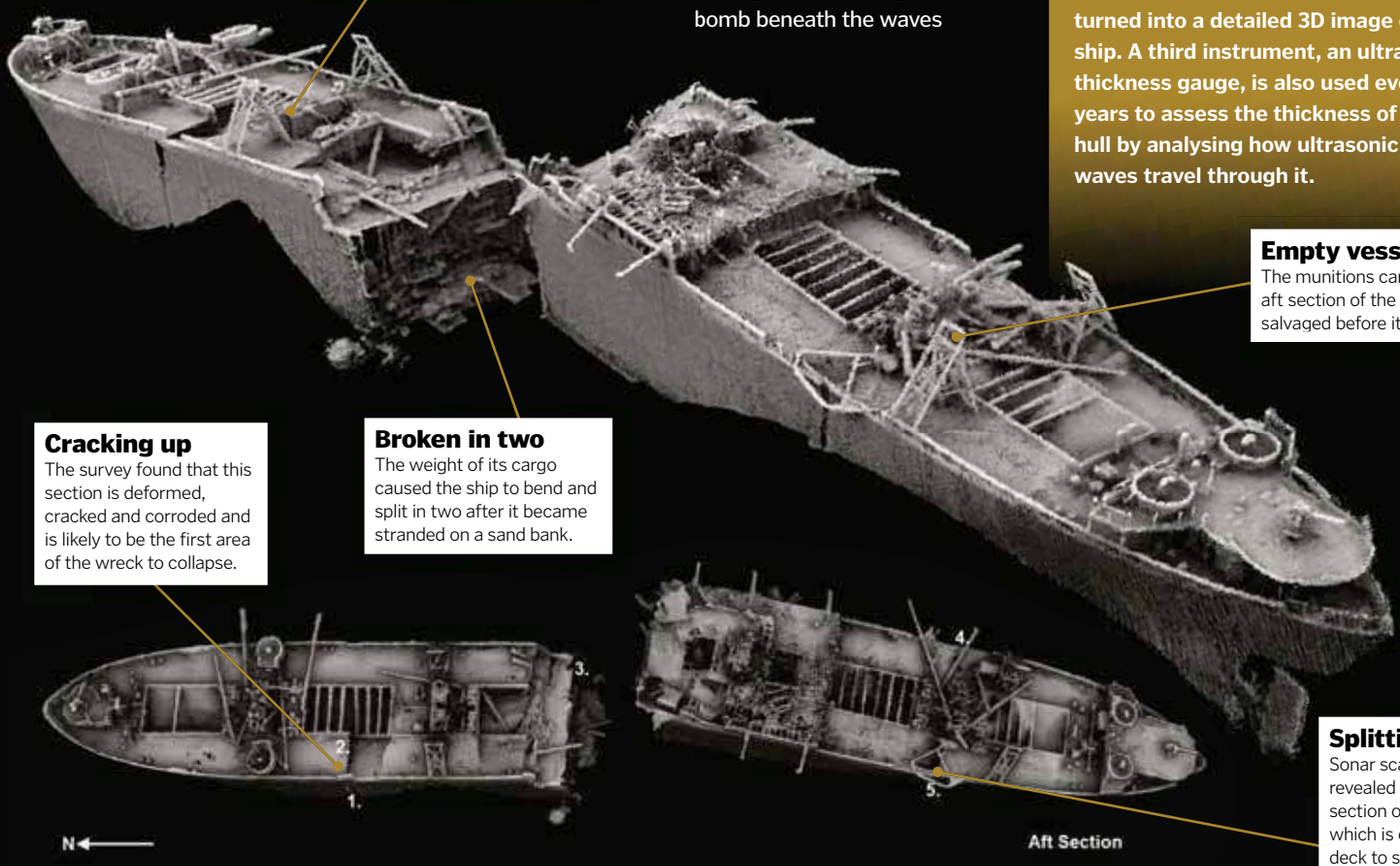
The SS Richard Montgomery lies in the mouth of the Thames just 2.4km from the shore

How the wreck is monitored

The SS Richard Montgomery is surveyed every year using two key techniques. Multi-beam sonar is used to study the submerged parts of the vessel and works by emitting sound waves in the direction of the ship and measuring how long it takes for them to bounce back. Meanwhile, laser scanning is used to study the parts of the vessel that are above the water and works in much the same way but with lasers instead of sound waves. The data recorded using both methods can then be combined and turned into a detailed 3D image of the ship. A third instrument, an ultrasonic thickness gauge, is also used every ten years to assess the thickness of the ship's hull by analysing how ultrasonic sound waves travel through it.

A crumbling wreckage

Mapping out the ticking time bomb beneath the waves



Explosive cargo
The forward section of the ship still contains approximately 1,400tn of munitions.

Empty vessel
The munitions cargo in the rear aft section of the ship was salvaged before it sank in 1944.

Broken in two
The weight of its cargo caused the ship to bend and split in two after it became stranded on a sand bank.

Cracking up
The survey found that this section is deformed, cracked and corroded and is likely to be the first area of the wreck to collapse.

Splitting image
Sonar scanning has revealed a split in this section of deck plating, which is causing the deck to slowly collapse.

Iguanodon anatomy

Explore the inner workings of this herbivorous giant

Balancing act
It's now believed that the Iguanodon would have remained balanced by holding its long, heavy tail in the air.

Hind limbs
The two longer – and likely more muscular – limbs would have been the Iguanodon's main locomotive force.

The Iguanodon

Unearth one of the very first dinosaurs to be discovered by humankind

It's very easy to find ourselves captivated by big, fearsome carnivores. We imagine them prowling the plains and forests of the Mesozoic Era, stalking and hunting the peaceful herbivores and roaring with vindication as they overcome their prey and claim a meal. But we often neglect to pay attention to their prey, to the herbivores that have merited an equal place in natural history. Some – such as the Iguanodons – also have a key place in our own history, marking a milestone in our fledgling efforts to study dinosaurs.

When its fossils were uncovered in England in the early 19th century, the Iguanodon was only the second ever genus to be classified as a dinosaur. After recognising that the newly discovered specimen had teeth similar to an iguana's, the Iguanodon earned its name and planted the seeds for the later realisation that dinosaurs had been, in fact, reptiles. Our perception of the Iguanodon has vastly changed and developed through the years, and today we can enjoy a fairly clear picture of how this hulking herbivore would have lived over 100 million years ago.

Iguanodon species existed in the Late Jurassic and Early Cretaceous periods. They had evolved to become effective grazing animals: with a flexible jaw for chewing; flat, rigid teeth for grinding fibrous plants; and the ability to stand back on two legs and use their ten-metre-long bodies to reach the highest leaves.

It's thought that Iguanodons would roam in herds for protection, similar to the herbivorous mammals of today, especially as they lacked the formidable horns and armour of other dinosaurs. However, they may have benefitted from the presence of other such herbivores, as multiple species journeyed together for mutual protection. Their world, like ours today, was a competitive one. But despite this the Iguanodon was able to prosper in many regions, including modern-day North Africa, Europe, Asia, Australia and North America.

Thumbs-up for Iguanodons

The Iguanodon's hand anatomy has captivated palaeontologists since its discovery. The species possessed a five-digit hand composed of three thick, blunt fingers, one unbound fourth finger that protruded laterally from its palm, and an intriguing thumb-spike. We understand that the spike originated via fused thumb joints, but its function remains a mystery.

Some have postulated that the spike's primary use was for defence, either from potential predators or from rival Iguanodons. They argue that the dinosaur would have used the sharp thumbs to stab at opponents when engaged in close combat. Some go further and suggest that the spike may have housed a venom gland, adding an extra layer of lethality to the hand-wielded weapon.

Others believe the curious feature had a more peaceful purpose. It may have simply been used for breaking into nuts and seeds, or potentially for stripping foliage from trees before consumption.

It is still unknown whether the Iguanodon's thumb-spike was used for foraging or fighting, or both

Vegetarian teeth
The Iguanodon's sloped, lizard-like teeth gave the dinosaur its name. Their ridged surfaces helped the herbivore grind through tough vegetation.

Manoeuvrable jaw
Many bones in the Iguanodon's skull had movable joints, allowing it to enjoy flexibility when chewing.

Digesting fauna
Although we cannot know for certain, the Iguanodon's digestive tract likely housed many bacteria that aided in the digestion of plant material.

Front limbs
The Iguanodon's versatile front limbs were used for walking, foraging and possibly for defence.

Dimensions
At around ten metres long and two metres tall at the hip, the Iguanodon weighed around four tons.

5 FACTS ABOUT THE IGUANODON

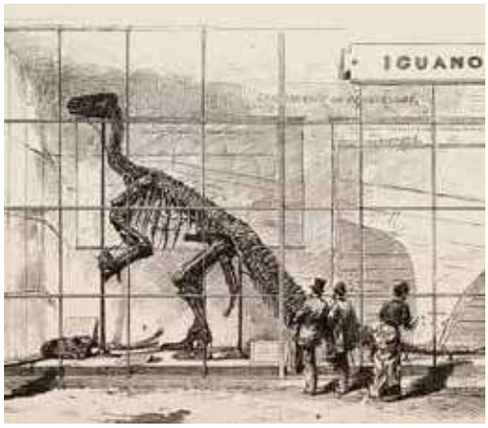
1 One of the first
The first Iguanodon fossils were discovered in West Sussex, England, in 1822. Behind the Megalosaurus, this made the Iguanodon only the second species to be officially recognised as a dinosaur in 1825.

2 Gaining its name
Dr Gideon Mantell named the Iguanodon on the basis of bone fragments and several teeth. He likened the teeth to an iguana's, earning the species (and later genus) its name.

3 Early errors
Unsure of what pieces of skeleton he had, Mantell originally placed the spiked, horn-like fossil atop the nose of his dinosaur reconstruction. It was later revealed to be the creatures' thumb.

4 A large find
In the 1870s, miners in Belgium found a collection of 30 relatively complete Iguanodon skeletons. This finding helped to vastly improve our understanding of their anatomy and suggested that the dinosaurs may have lived in herds.

5 Kangaroo to something new
For many years the scientific community believed the Iguanodon was a pure biped, bearing a similar stance to today's kangaroo. However, we now believe Iguanodons were horizontally aligned and only semi-bipedal.



For years scientists believed that the Iguanodon moved in an upright posture similar to a kangaroo


Like many herbivorous dinosaurs, the Iguanodon was a giant. Its height was a useful asset for reaching food

STRATEGY GUIDE

Dragon Castle

Help your realm rise to power in this Mahjong-inspired tile game

- Publisher: **Cool Mini Or Not & Horrible Games**
- Price: **£46.99 / $49.99**
- Number of players: **2–4**
- Ages: **8+**
- Typical game time: **45 mins**

In this beautifully designed game you take on the role of a lord striving to build a new city from the ruins of the fading Dragon Castle. To create a prosperous new home you must build shrines, enlist the help of the spirits and win the favour of the elder dragon.

The game's symbols will be familiar to anyone who has played Mahjong solitaire. Players take turns collecting tiles emblazoned with these symbols from the old Dragon Castle and add them to their realm board. Collecting at least four tiles of the same type and placing them adjacent to one another enables you to consolidate them and start building shrines to earn more points.

Once players have got to grips with the rules they can add an extra challenge by introducing spirit and dragon cards. Spirit cards enable you to sacrifice tiles in order to gain special abilities, such as being able to build an extra shrine, while constructing your new castle in a certain way can potentially earn you extra points with dragon cards.

The final round begins once all of the countdown tokens have been collected, and the player with the highest total of victory point tokens and shrine points is the winner, with their realm gaining the favour of the elder dragon.

Building a new realm

Winning the elder dragon's favour requires planning and patience

Tile types
There are six different tiles within two main categories. 'Faction' tiles include merchants, farmers and soldiers, while 'special' tiles include seasons, winds and dragons.

Dragon Castle
Before the game begins, you must assemble the Dragon Castle using all the 116 available tiles. Once familiar with the game you can start using some of the alternative layouts, or design your own.

Shrines
Once you consolidate a set of tiles you can start building shrines. The higher the shrine, the more points it is worth, so you might want to bide your time to build taller ones.

First player token
As per the rules, the player who most recently saw a dragon takes the first turn. So if you want the upper hand, perhaps you should re-watch some *Game of Thrones*?

Countdown tokens
Once the Dragon Castle only has tiles left on its ground floor, players have the option of taking a countdown token on their turn to speed up the end of the game and put pressure on the opposition.

Building
Each player builds their new castle on a realm board (not shown). Matching tokens must be placed adjacent to one another in order to be consolidated – diagonals don't count.

Spirit guides
Players can use the spirit or dragon cards to give themselves a special ability or boost their points.

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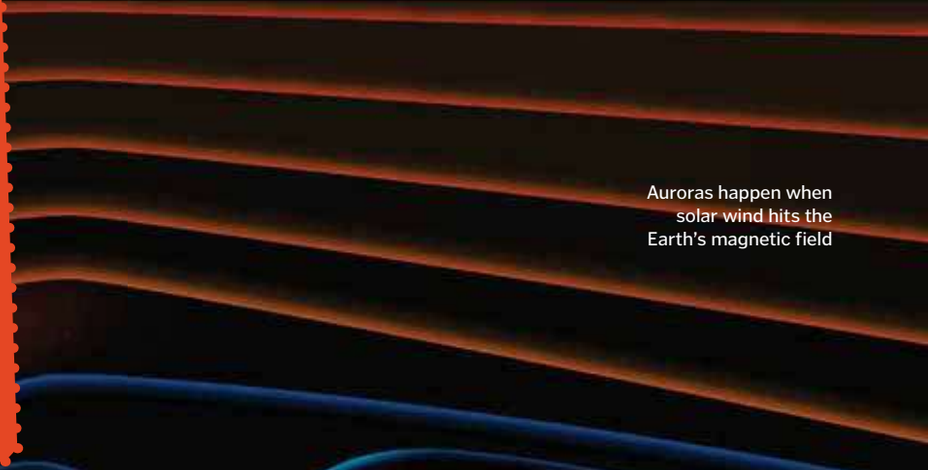
BRAIN DUMP

Because enquiring minds need to know...



Auroras happen when solar wind hits the Earth's magnetic field

MEET THE EXPERTS

Who's answering your questions this month?

JODIE TYLEY

TOM LEAN

LAURA MEARS

JAMES HORTON

JO STASS

Why don't auroras occur closer to the equator?

Rachel Jennings

If you could see magnetic fields, the Earth would look a bit like a bar magnet, with field lines emerging from the north and south poles. It forms a protective shield that helps to deflect incoming space weather, such as solar wind. The Sun throws out jets of charged particles, which press on the magnetic field as they pass. These particles zip along the field lines, heading towards the poles, where they curve in towards the Earth. Here, they crash into gasses in the atmosphere, transferring their energy to the air. When the gasses release the energy again, it comes out as colourful packets of light. **LM**

What was the first supercar?

Ben Jacobs

Many experts agree the first modern supercar was the Lamborghini Miura, a stylish 1966 sports car that was the world's fastest production car when it was released and introduced design features common to supercars today. However, even before this people had already been calling fast and powerful cars 'supercars' since the 1920s. **TL**

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Why do some materials make you prone to static shocks?

Jelka van Hoek

Static electricity forms when materials rub together and either gain or lose negatively charged electrons, causing a negative or positive charge to build up (respectively), which can cause a shock when discharged. Some materials lose or gain electrons more easily than others, and wearing these makes you prone to static shocks. **TL**

What does vitamin A do?

Ellie Stephens

Vitamin A forms part of the light-sensing pigment rhodopsin, which enables us to see in dim light. It also helps to maintain the immune system, the skin and the membranes that line the nose, mouth and digestive system. Vitamin A deficiency can cause blindness, increased risk of infection and dry, scaly skin, but too much can be dangerous too. In 1913, an Antarctic explorer lost his life after accidentally overdosing on vitamin A by eating dog's liver. **LM**

What is gruel?

Elisha Gorshkov

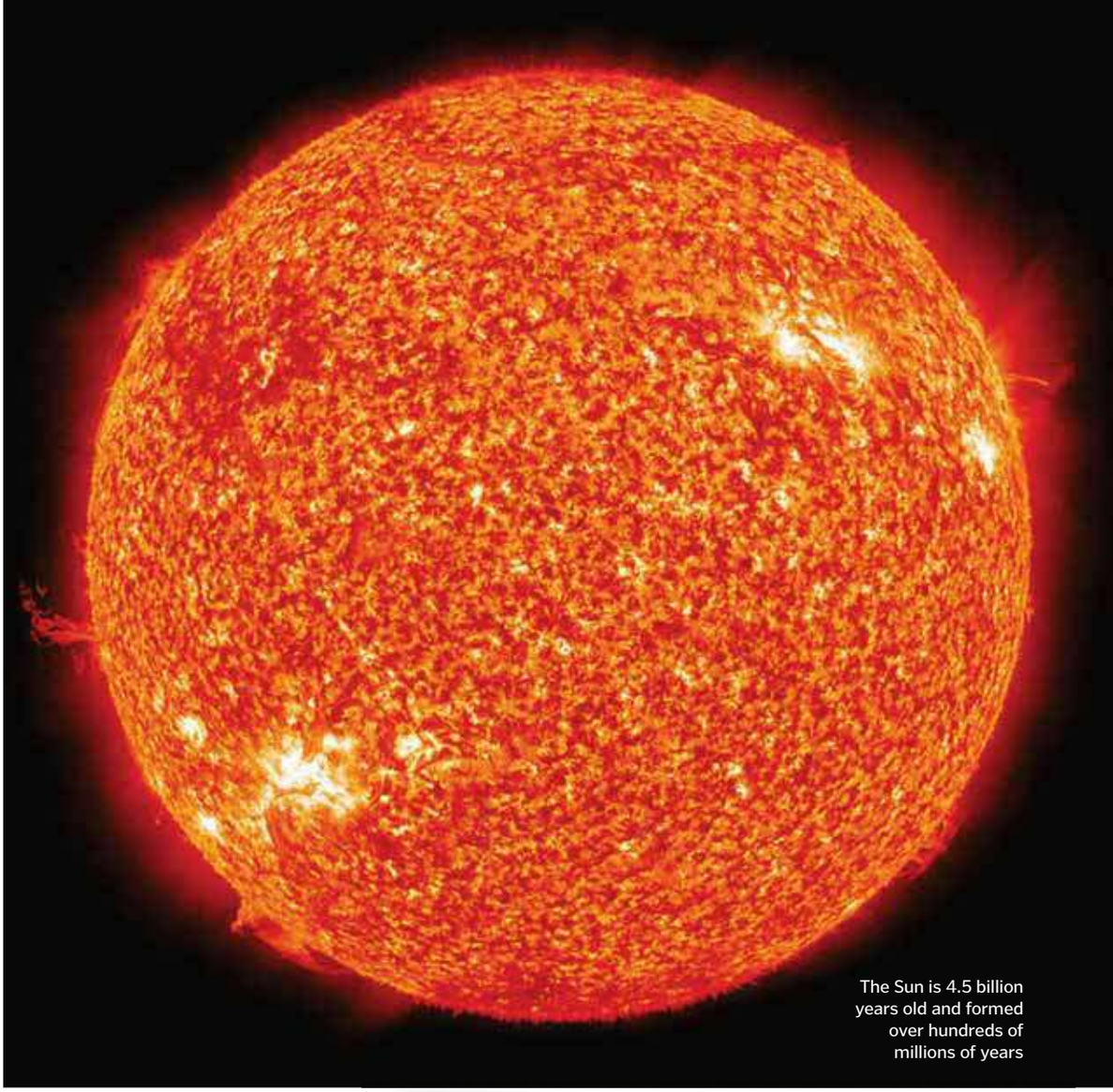
Gruel is a runny, porridge-like mixture of boiled water and either oats, wheat or rice. Often associated with Victorian workhouses, this dish has actually been served since ancient times. **JT**

BRAIN DUMP

How did the Sun form?

Maddie Ferguson

Scientists think the Sun began as a giant gas and dust cloud rotating in space. Over millions of years, as this spun faster, the cloud collapsed into a disc. Some of the material around the disc formed the planets as small clumps of material stuck together, but most of the gas and dust was pulled into a large mass in the middle, a body that became the Sun. At its centre the temperature and pressure became so enormous that a thermonuclear reaction started, smashing atoms together to release energy and starting the fusion chain reaction that makes the Sun 'burn'. **TL**



The Sun is 4.5 billion years old and formed over hundreds of millions of years

Automatic transmission cars are often better for urban driving

Are automatic transmission cars better?

Matt Foster

There are pros and cons to both manual and automatic transmission, so your preference will depend on the type of driving you do. Cars with automatic transmission are a lot simpler and smoother to drive in slow-moving traffic, as you don't need to constantly shift gears yourself when you stop and start. This also means there is less chance of grinding the gears, making the transmission less likely to fail. On the other hand, manual transmission cars are often cheaper, particularly when it comes to getting them repaired, and they give you more control over the car. **JS**

UHT milk is cheaper to transport as it does not need refrigeration

How is UHT milk made?

Hayden Fry

To remove any harmful bacteria, the milk kept in the refrigerated aisle of the supermarket is pasteurised by heating it to 72 degrees Celsius for at least 15 seconds, then cooling it down. However, this means it has a limited shelf life of up to 15 days. Ultra-heat-treated (UHT) milk is pasteurised by heating it to 140 degrees Celsius for just three seconds before cooling. This means it can be stored at room temperature for months. **JS**

The coffee trade began on the Arabian Peninsula

When did humans first begin drinking coffee?

Rosie Kay

The first known reference to drinking coffee was made in 900 CE in an Arabic medical textbook. However, it wasn't until the 15th century that the coffee industry took off in the Arabian Peninsula. Coffee houses became popular as places where people could drink, gossip and listen to music. These social hubs eventually spread throughout Europe, where coffee received mixed reviews. In 17th-century Venice it was declared 'the bitter invention of Satan' until Pope Clement VIII gave the beverage his official approval. **JT**

Why do people put chains on tyres in snowy weather?

Maya Kirby

Snow makes road surfaces slippery, reducing friction. Cars can't cling to the ground, making steering, starting and stopping more difficult. Chains sink into the snow, grabbing hold of the surface and giving the wheels something to pull against. **LM**

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What's the difference between HD and Ultra HD TV?

Sara Nguyen

An HD picture is made up of over 2 million dots, or pixels. With over 8 million pixels, Ultra HD displays have a higher resolution and give a much sharper picture. **TL**

Why are helicopters so incredibly loud?

Bill Smith

According to the German Aerospace Center, most of the noise comes from the blades. The blades create a vortex as they spin, and when they hit the moving air they vibrate, resulting in noise. **LM**

Is it true that only ten per cent of Americans have passports?

Julie Lung

No, that hasn't been true since 1994. Currently, more than 40 per cent of American's have passports, but that's still lower than in England and Wales, where over 76 per cent have a UK passport. **JS**

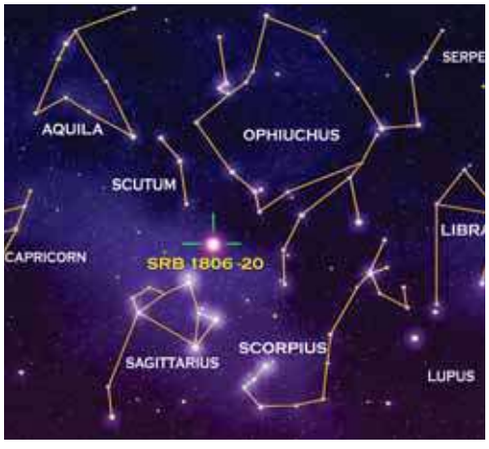
BRAIN DUMP

The Mars 2020 rover will collect samples and search for signs of life

What will the Mars 2020 rover do that Curiosity can't?

Bailey Dawson

The Mars 2020 rover will, at first glance, look very familiar to the Curiosity rover that came before it. Even so, 2020 will accomplish grand new goals thanks to its seven novel instruments, improved wheels and enhanced autonomous capabilities. The next rover will allow us to peer about ten metres below Martian rock and ice for the first time, probe and characterise chemical compositions of rock and dirt on the surface, and collect and store samples for a future return mission. **JH**



What is a constellation?

Brad Lane

A constellation is a group of stars that forms a shape in the sky and has been given a name. There are 88 recognised constellations, and over half of these were identified by the ancient Greeks, who based their knowledge on information acquired by even earlier civilisations, such as the Babylonians. Throughout history, people have made up stories about constellations, and many bear the names of mythical gods and beasts. **JT**

Roundabouts are found in the US, most commonly in Florida, but they remain relatively unpopular

Why are there so few roundabouts in America?

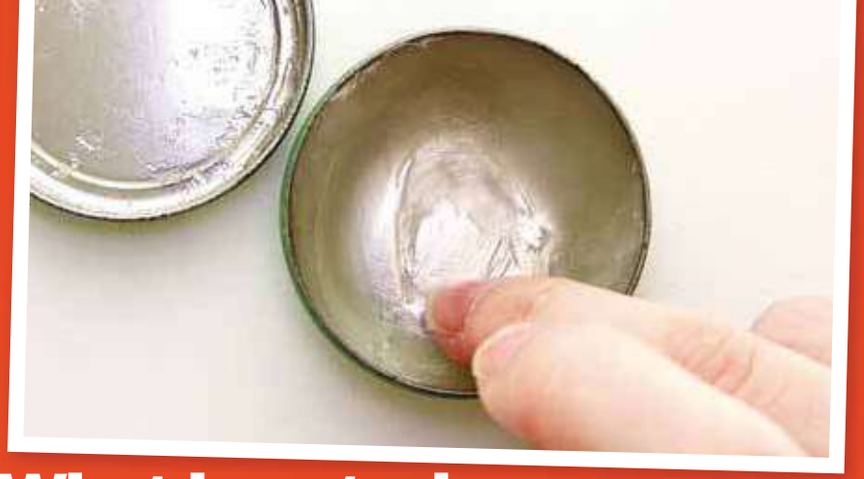
Jonas Barends

The UK has a passion for roundabouts; we even have our own Roundabout Appreciation Society. Other nations, including Australia and France, have even more of the circular traffic guides. But this love has yet to be exported to our American cousins. The US does have roundabouts – one per 1,118 intersections, compared to one per 127 in the UK and one per 45 in France – but many regulators and officials still heavily favour the traffic light intersection. Although there is evidence that roundabouts are the safer option, many cite an entrenched culture that dislikes changes to the roadway and the psychological benefit of having a traffic light as a guide as reasons for the US's reluctance to join the roundabout revolution. **JH**

Why does hot weather make you tired?

Aiden Stones

Your body is using a lot of energy to maintain its internal temperature of 37 degrees Celsius. Blood vessels dilate so that more warm blood can flow closer to the surface of the skin to lose heat, which is why some people's faces turn red temporarily. You also sweat more, which cools the skin as it evaporates, but in order to do this your heart pumps faster and your metabolic rate (and therefore the number of calories your body needs) also increases. All this extra work can leave you feeling tired, and dehydration can only make it worse as your body loses water through perspiration. **JT**



What is petroleum jelly and why is it used in skincare?

Dagmar Rulfová

Petroleum jelly, or petrolatum, is a refined and purified byproduct of the oil drilling process. It contains a mixture of natural waxes and mineral oils that work to seal in moisture when applied to skin, helping to prevent it from becoming dry or chapped. **JS**

Want answers?

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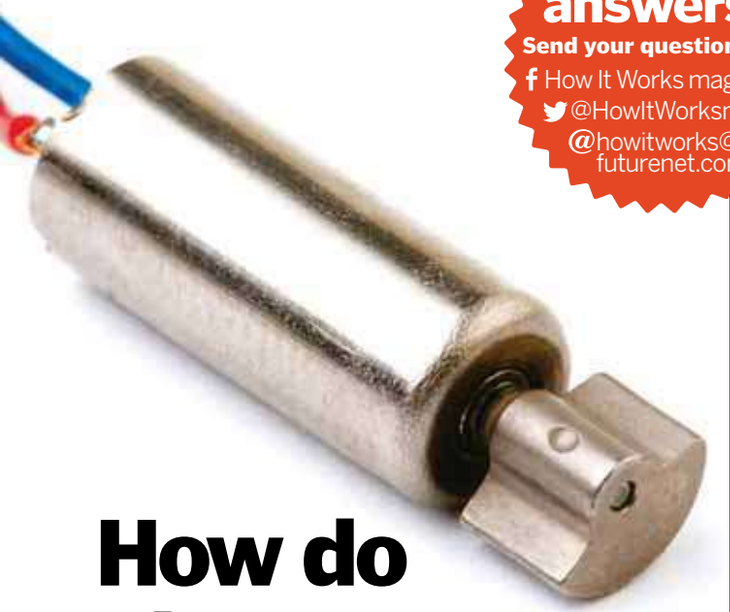


How do phones vibrate?

Nina Tvedt

Many phones feature a simple motor that spins an off-balanced segment attached to its shaft. This uneven weight distribution causes the phone to vibrate when the segment is rapidly revolved. **JH**

Do we know which planet in our Solar System formed first?

Megan Watts

The current expert opinion points to our Solar System's resident giant, Jupiter, as the first to have formed around 4.5 billion years ago. A recent study argued that if Jupiter had formed as a rocky core only 1 million years after the Sun (around 50 million years before Earth), it would have carved a gap through the Sun's accretion disc. Over the next few million years the core grew to 50 times the mass of Earth and accumulated large amounts of gas to form the giant that we see today. **JH**

BOOK REVIEWS

The latest releases for curious minds

Schrödinger's Cat and 49 Other Experiments that Revolutionised Physics

History and science wrapped into one

- Author: **Adam Hart-Davis**
- Publisher: **Modern Books**
- Price: **£12.99 (approx. $17)**
- Release date: **Out now**

A lot of the books we've reviewed recently have combined history lessons with science. It's a perfect match – it would be almost impossible to understand why Eratosthenes tried to work out the size of the Earth using shadows if you didn't first understand the methods people used to measure distance in 230 BCE, and how the ancient Greeks already knew that the Earth was a globe, not a flat circle. This book takes the same approach, and the historical backdrop serves as the perfect introduction to each new idea.

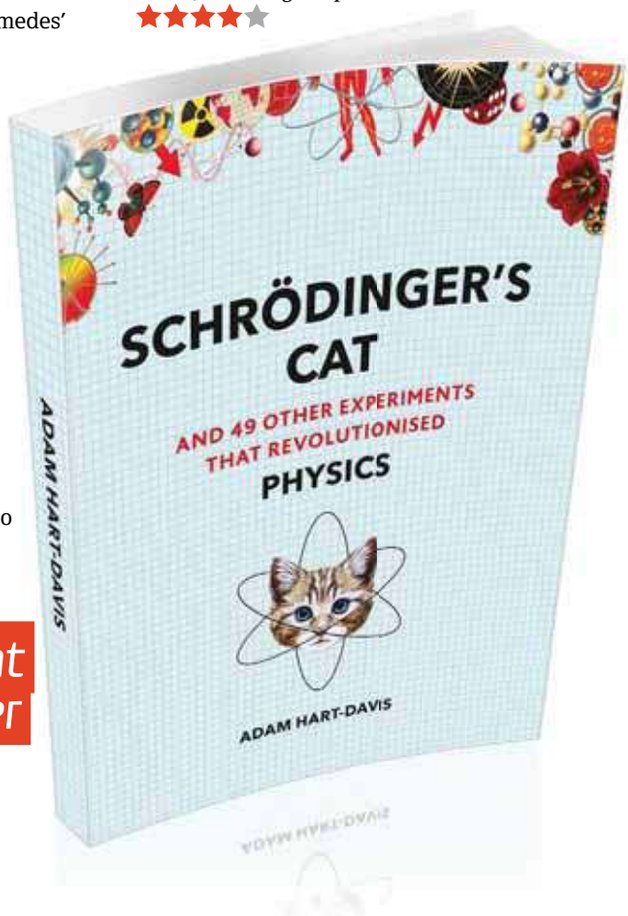
As a result, it's an excellent intro for readers wanting to know more about famous scientists. It's also fantastic as a refresher for those who have perhaps forgotten some of the details of Einstein's theory of relativity or Archimedes' bath-time breakthrough.

However, the book's primary aim is also its downfall at times. By keeping each experiment brief and snappy and explaining theories and studies in just a few pages, some of the details can be lost. Don't get us wrong, Hart-Davis has done an excellent job of packing plenty of interesting information into the sections and does so without waffling, but there are times when you feel that a certain idea or theory needs more explanation than just a paragraph or two.

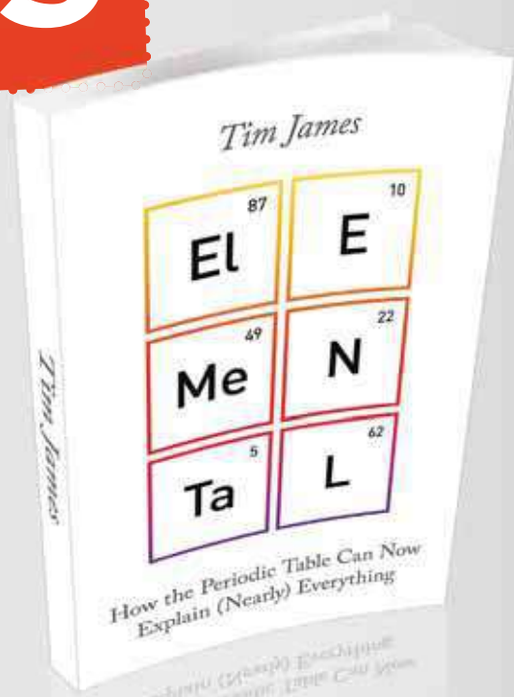
That said, the pacing of the book also means that if you do come across an experiment or theory that you find a little dull, you won't be stuck with it for long. The fast-moving topics make it easy to pick up the book and breeze through several decades of research in just a single sitting, and if you only have a few minutes, you can read just a few pages and put it down again, without needing to leave a topic halfway through.

Again, the writing style helps to keep things entertaining throughout and ensures even the most complex ideas are easy to read and understand. Illustrations don't do much to add to the narrative but do brighten up pages – they might put off serious scientists, but this isn't really for them in the first place. If you're just an amateur looking to find out more about the world, this is a good place to start.

★★★★☆



"It's an excellent intro or refresher for readers"



Elemental: How the Periodic Table Can Now Explain (Nearly) Everything

Life, the universe and almost everything

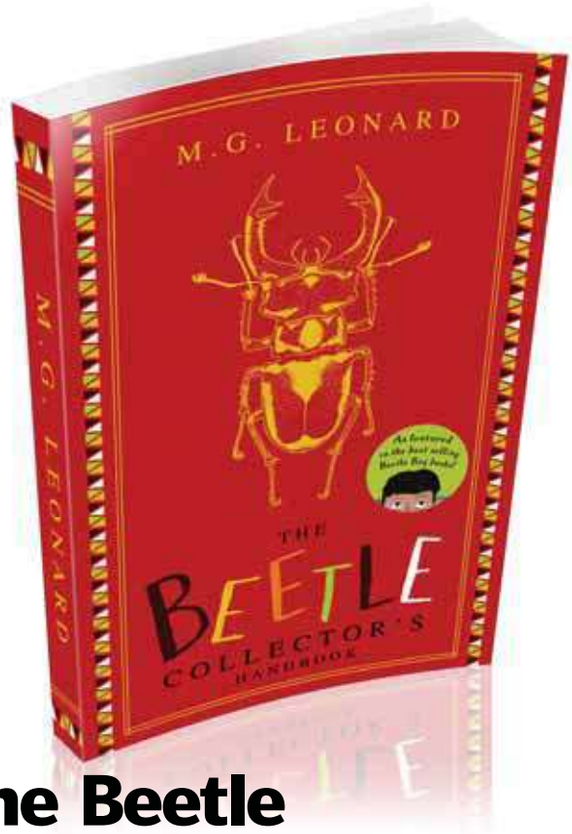
- Author: **Tim James**
- Publisher: **Robinson**
- Price: **£12.99 (approx. $17)**
- Release date: **Out now**

Learning can – and should – be fun, but let's face it, science at school wasn't always the most interesting thing in the world. Take the periodic table, for instance. Nestled among that severe-looking mass of numbers and symbols are the building blocks of the universe. So much possibility – pity it isn't all that much to look at.

Tim James takes this notion and runs with it, delivering all sorts of facts and figures that will provide a real incentive to dive back into the periodic table. From poisons and mass-producing food to the secrets of the stars themselves, it's no secret that the elements have a hand in everything, but sometimes it takes a writer as talented as James to efficiently articulate just how important it is.

It'll take some incentive to read this unless you're anything less than an über science buff, but you'll be missing out if you don't.

★★★★☆



The Beetle Collector's Handbook

Cutting insects down to size

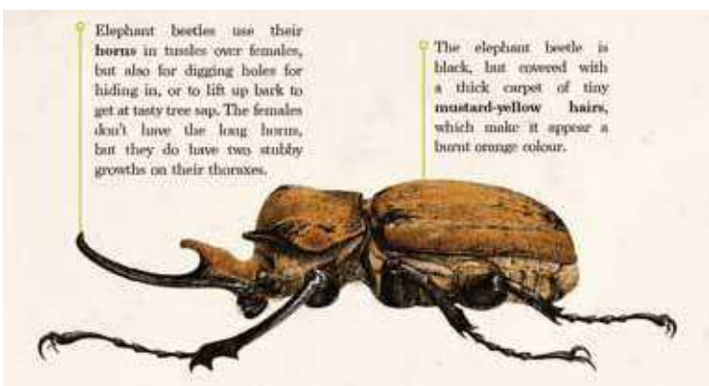
- Author: **M G Leonard**
- Publisher: **Scholastic**
- Price: **£10.99 (approx. $15)**
- Release date: **Out now**

"If you need to find out anything about beetles you need to read this book, I've found out loads." So reads the annotated introduction to this book, which is essentially – as the title indicates – a guide to assorted insects, with annotations from two wonderfully named young brothers, Bartholomew and Darkus Cuttle, providing commentary throughout.

Beginning by making a welcome attempt to bridge the gender divide in this field by banishing any kind of gender bias, this proceeds to become an all-encompassing guide to some of the animal kingdom's smallest members, with beetles bearing such evocative names as rhinoceros, titan and Goliath all going under the microscope, so to speak, along with many more.

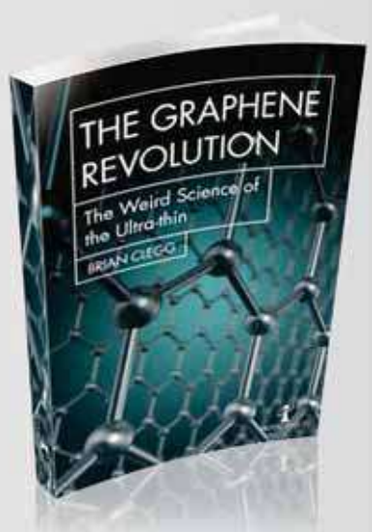
It's hard to find any fault with this: the presentation and art direction are lovingly implemented, the chapters are full of accessible yet non-patronising information – even the paper quality is great. In other words, go and buy this.

★★★★★



The Graphene Revolution

The metal marvel



- Author: **Brian Clegg**
- Publisher: **Icon Books**
- Price: **£8.99 / $14.95**
- Release date: **Out now UK / 16 October US**

Much has been made of the potential applications of graphene. From making long-distance space travel possible to aiding the disposal of toxic waste, it could change everything – but so far it hasn't.

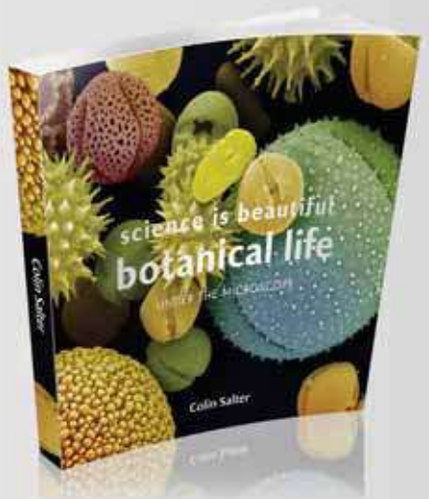
Regardless, the capacity for innovation is still there, and it is these applications that Brian Clegg is interested in, exploring them as part of the fifth instalment in his *Hot Science* series. Relating its importance with regards to the field of quantum physics, he proceeds to demonstrate exactly how it has been used to date – while it certainly seems very much like baby steps, it feels like there's a lot more that can be achieved.

While there's a lot to enjoy here, it's not always the easiest to understand. Unless you have a decent understanding of quantum physics it's likely that large parts of this will go over your head. If so, then you might be advised to try something a tad more accessible.

★★★☆☆

Science is Beautiful

Botanical life under the microscope



- Author: **Colin Salter**
- Publisher: **Batsford**
- Price: **£20 / $35**
- Release date: **Out now**

Here at **How It Works** we all like a good coffee table read – the brighter and bolder the better – which is why we were glad to see this arrive in the office: a book that is both attractively laid out and lovingly compiled, while at the same time sufficiently informative.

So much effort is put into explaining the building blocks of science that we don't always take the time to sit back and reflect on just how wonderful and awe-inspiring it all is. Luckily, Colin Salter has, providing all sorts of close-up, and sometimes microscopic, shots that seem almost alien but are in fact all Earthbound. There are plenty of surprises too; you wouldn't believe slime mould spores could be so eye-catching.

Sure, its appeal may ultimately be limited, but it's great to flick through every once in a while, which in all honesty is really all you'll want it for.

★★★★☆

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

W	F	M	E	L	Y	X	E	G	C	V	I	H	D	P
B	C	H	I	M	P	S	H	A	K	L	M	E	O	I
D	G	R	G	D	A	J	U	V	M	B	F	T	U	B
M	O	Q	U	M	I	P	A	T	O	I	R	N	G	X
I	U	J	A	T	N	Z	W	F	B	D	W	Y	H	D
C	S	P	N	G	C	K	E	R	P	O	J	E	K	Z
R	S	D	O	A	U	V	I	F	G	X	P	C	L	A
O	E	T	D	M	P	L	U	N	K	Q	A	R	F	H
R	N	A	O	W	L	E	O	Y	T	P	S	O	Y	R
N	E	R	N	A	S	Z	X	P	F	B	U	F	J	T
A	D	F	T	V	A	Q	J	L	Z	N	G	E	W	L
J	U	O	H	M	B	M	O	C	A	H	I	C	P	S
E	R	L	A	I	K	W	N	V	S	G	B	A	M	T
I	K	C	O	Q	F	A	Y	A	M	K	X	P	F	N
B	P	A	R	K	E	R	S	O	D	E	W	S	C	A

FIND THE FOLLOWING WORDS...

AMAZONGO
ANTS
CHIMPS
DEFIBRILLATOR
DOUGH
HUAWEI
IGUANODON
MAYA
MICRORNA
NAVY
PAIN
PARKER
RUDENESS
SPACEFORCE
VLBI
WOLFPACK
XYLEM

Quickfire questions

Q1 In what year was the first Wimbledon Championship held?

- 1877
- 1887
- 1897
- 1907

Q2 Which of the following was not US President?

- Andrew Jackson
- William Harrison
- Benjamin Franklin
- Andrew Johnson

Q3 What is the gravitational constant, G?

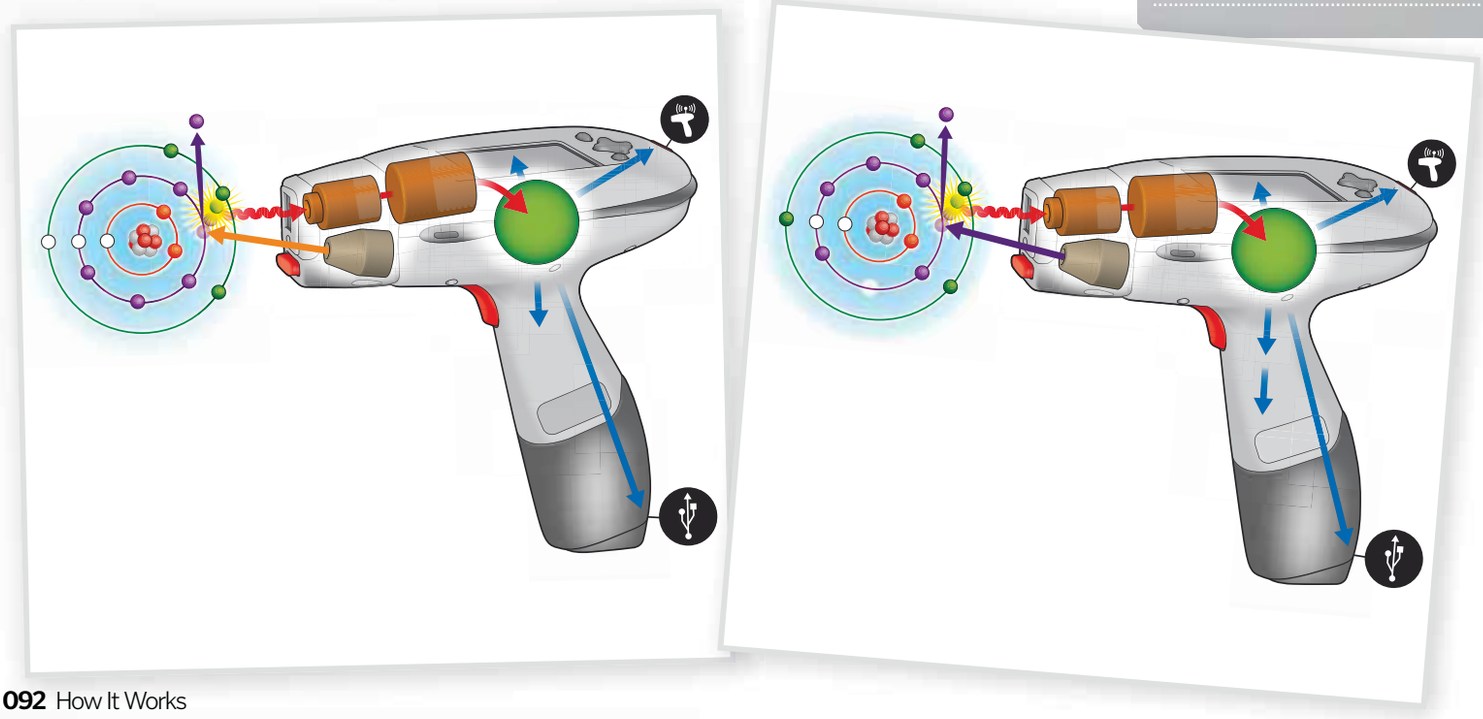
- = $6.67 \times 10^{-11} m^3 kg^{-2} s^{-2}$
- = $6.67 \times 10^{-11} m^2 kg^{-1} s^{-2}$
- = $6.67 \times 10^{-11} m^3 kg^{-1} s^{-1}$
- = $6.67 \times 10^{-11} m^3 kg^{-1} s^{-2}$

Q4 Animal cells are ____

- Eukaryotic
- Prokaryotic
- Both eukaryotic and prokaryotic
- Neither eukaryotic nor prokaryotic

Spot the difference

See if you can find all six changes we've made to the image on the right



Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

	7							4
6		9		4			5	7
4			7	8	3		9	6
		5			7			3
			6	9	4			
8			3			6		
9	4		2	6	8			5
5	2			3		7		9
3							2	

MEDIUM

5			4				2	8
7				6				3
					2	4		5
	9			4		5		
	7	6		5		1	4	
		2		7			3	
2		9	3					
8	1			2				7
6	3				9			

What is it?

Hint:

Can hurt if you're not careful

A .....

© Getty

Spot the difference

Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

Q1 1930

Q2 A young hare

Q3 Intercostal

Q4 Left and right

What was it?

An orange

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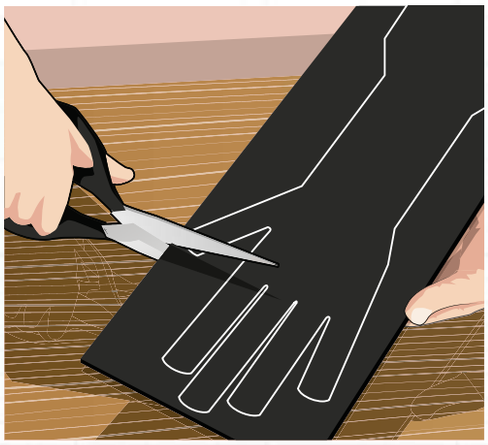
howitworks@futurenet.com

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

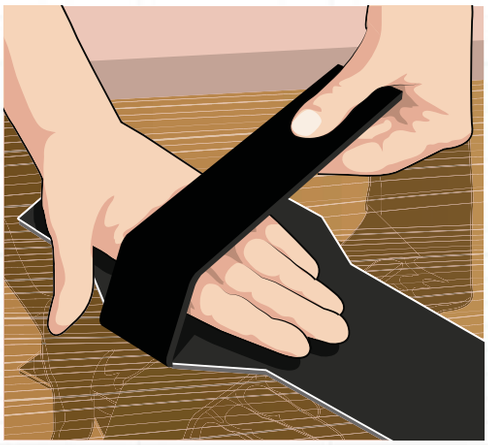
How to make a mechanical arm

Craft an arm with fingers that can grip using objects from around your home



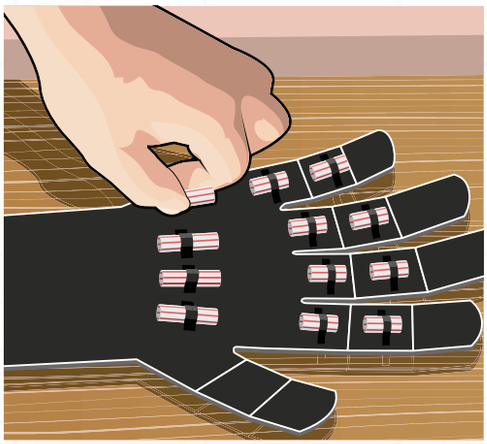
1 Make the arm

First, cut an arm shape out of a piece of thick, corrugated cardboard around 40cm long, with a hand at the end. Try to have the corrugated lines perpendicular to the arm's length. At the elbow end of the arm shape make sure the arm widens slightly (your hand will need to fit here later). Then cut two more pieces of cardboard – one that's 4 x 32cm and one that's 4 x 35cm.



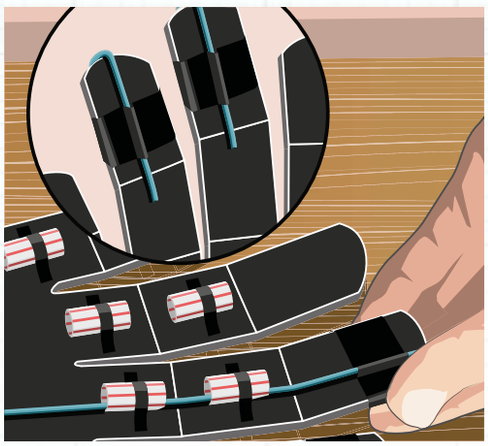
2 Hold your hand

You now need to decide whether you want to create a left or right hand. If you want to use it as a right hand, place the card 'palm down' on the table and stick the shorter strip of card that you cut onto the arm to strengthen it. Then turn it back to the arm side and stick the longer strip to the wider part of the arm near the elbow. This is your handle.



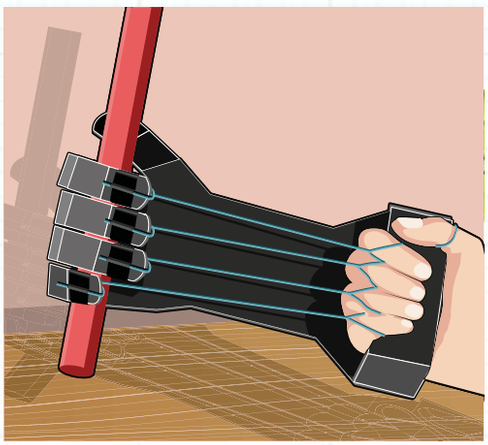
3 Finger grips

Now use a ruler to bend the fingers in three places. These are the joints of your mechanical hand. Now cut out eight small, 1cm sections of a plastic straw. Use thin strips of strong tape to attach these between the joints in the fingers. Then cut four longer, 3cm strips of straw and attach them to the palm so that they line up with the fingers.



4 Thread your fingers

Next, cut four lengths of thread, each around 40cm long. Wrap the end of one over the top of each finger on the model and tape them firmly to where the fingernail would be. Then feed the threads back over the top of the fingers and push them through the straws on the fingers and palm. They should reach your hand grip.



5 Grab-a-thon

Make a loop at the other end of each piece of thread big enough for your finger to fit through and tie a knot in them to secure it. Put your hand through the grip you created, then put your fingers in each loop. When you close your hand on the grip the fingers should close on your mechanical hand too!

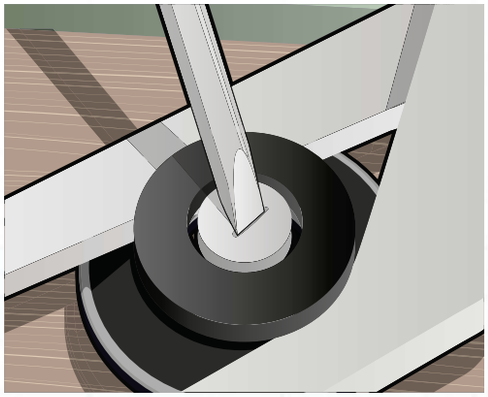
"When you close your hand on the grip the fingers should close on your mechanical hand!"

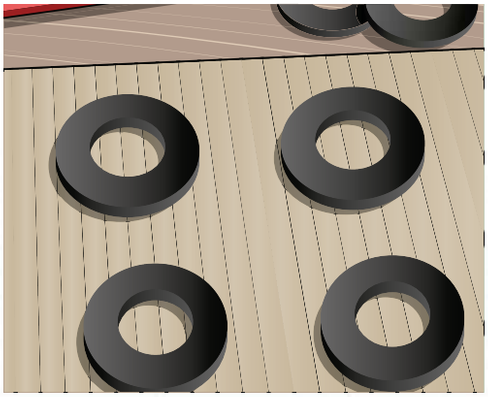
In summary...

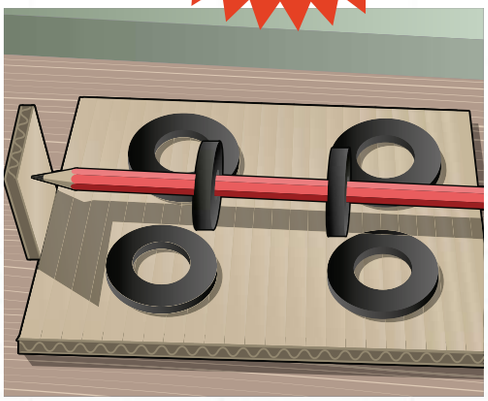
The thread here acts like the muscles in your forearms. The muscles are attached to strong, flexible bands of connective tissue called tendons. When you flex your muscles the tendons pull your finger joints inwards to close your hand – just like you're doing when you pull the threads on your mechanical arm!

Make a pencil float

Create a magical floating pencil using the power of magnets







1 Find the magnets

You'll need some powerful magnets to create your floating pencil. The best ones for this job can be found in speakers. Grab an old speaker with four outputs of the same size and ask an adult to help you take it apart. They'll need to use a screwdriver to prise the casing off the individual speaker then use a hammer and screwdriver to remove the parts inside. You should be left with one large, round magnet with a hole in the centre.

2 Make the base

You'll need four of these large magnets and two smaller ones – they can also be found in the speaker casings. Get a piece of card around 12 x 7cm. Draw two lines around 3cm in from each end, then two more about 1cm in from each edge. Find out which poles are on which sides of your magnets by holding them near each other. Put double-sided tape on the north pole of two of the magnets and on the south poles of the other two.

3 Float your pencil

Stick the two 'north' magnets on one end of the cardboard so that they touch the lines you drew. Then stick the two 'south' magnets at the other end, also touching the lines. There should be 1cm between the same pole magnets. Glue a small, vertical piece of card at one end of the base. Push the two smaller magnets onto the pencil and place it so the lead is touching the upright card. Adjust the magnets until the pencil floats.

"Place the magnets on the pencil, then adjust until the pencil floats"

In summary...

The two north pole magnets and two south pole magnets create a magnetic field pushing upwards from the base. The two magnets on the pencil are pushed away from this, and while the pencil would normally fall, the upright card stops this, so the pencil floats above the base.

NEXT ISSUE

CREATE COLOURFUL COSMIC EGGS

INBOX
Speak your mind...

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Focusing on the horizon or something in the distance can make you feel better if you're experiencing motion sickness

Letter of the Month

Car sickness

Dear **HIW,**
Why do people feel car sickness?
Augustine Gedge

Car sickness is really unpleasant and is experienced by around five to ten per cent of the population. It's a type of motion sickness, and the sensation can also occur when you travel by boat, plane or train. Even astronauts can experience motion sickness when they're in space. The symptoms are usually dizziness, nausea and sometimes vomiting, and they are caused by repeated movements when you're travelling in a vehicle, such as bobbing up and down in a boat or driving along a bumpy road. This leads to contradictory messages being sent to your brain – your inner ear tells it that you are moving, but your eyes just see the inside of the vehicle so they tell your brain that you are not moving.

Inside your ears are a network of tubes called the vestibular system. Within the system are three semicircular canals filled with fluid that move when you move your head and two sacs known as the saccule and utricle that signal to your brain to tell if you are lying down or standing up. As you get spun around on a roller coaster or tossed among the waves in a rubber dingy, the fluid is moving too. This results in confusing messages as to whether you're staying still or moving being sent to the brain, which can make you feel unwell.

There are a few things you can do if you suffer from motion sickness, such as limiting the movement you're experiencing by sitting in the front of the car or the middle of the boat. Fresh air, staring at a fixed point on the horizon, distraction and breaking up longer journeys into shorter legs can all help too.

WIN!
AMAZING PRIZE FOR LETTER OF THE MONTH!
TUTANKHAMUN: EGYPTOLOGY'S GREATEST DISCOVERY
Next issue's letter of the month will win this fantastic book on the discovery of Tutankhamun's tomb and what we have learned about the boy king's reign

Voice recognition

Dear **HIW,**
I recently purchased a Google Home speaker. I was wondering how voice assistants can use voice activation ('OK, Google', 'Hey, Siri' etc.) and differentiate voices (how it can tell my voice apart from my dad's). How long ago did these sorts of mechanisms come into everyday use?
Caden Blythman

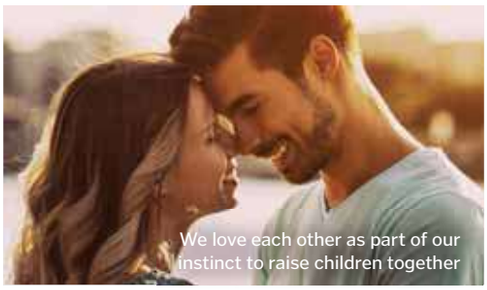
Voice assistants in our gadgets work by listening out for their activation phrase, such as 'OK, Google'. To do this, they are always linked to your device's microphone, but they will only start 'paying attention', as it were, once you say its specific key words.

The feature that recognises different voices in Google Home devices is called Voice Match. It can recognise up to six different voices using technology that links each speaker to their preferences, such as their favourite news source or the expected commute time to their place of work. When setting up Voice Match, users repeat the phrases 'Okay, Google' and 'Hey, Google' twice. This trains the Google Home to recognise the tone and pitch of your voice by creating a voice profile that it matches every time you speak to it. Other smart home assistants are introducing this system, including Amazon's Alexa.

Voice recognition software itself has existed since 1961, when IBM introduced their Shoebox tool, which could recognise just 16 words: the digits 0–9 and arithmetic commands such as 'plus' and 'minus' – effectively a basic voice-activated calculator.

Clearly the technology has evolved dramatically since then, with smart speakers able to understand and respond to normal speech with the help of rudimentary artificial intelligence software. These technologies have become more widespread in recent years ever since Apple introduced Siri in 2011 and Amazon launched their first Echo speakers in 2014.

The Google Home is one of the first pieces of tech that can distinguish different voices



We love each other as part of our instinct to raise children together

Science of love

Hi **How it Works,**
I was wondering what is the point of humans falling in love? And how did our brains evolve for us to do this?
Thank you,
Sophie Catherine

Love serves an important evolutionary purpose; it keeps us close together, and our survival depends on each other from the moment we're born. Love evolved for a few complex reasons, but one example is our big heads. As our heads started to get larger due to our bigger brains, we were born a lot earlier and a lot less developed. This meant parents had to love their offspring and stay with them to make sure they survived. The feeling of being in love is generated in response to hormones in our bodies. For example, dopamine and noradrenaline are released when we are attracted to someone, triggering feelings of 'butterflies' and giddiness.

Waste on cruise ships is treated and then pumped into the ocean or destroyed

Cruise ship loos

Hi **HIW,**
Where does poop go on a cruise ship? Does it get dumped into the ocean?
Tom

Don't worry – your poop doesn't get dumped into the ocean when you're on a cruise ship. Instead, it is sucked through to a series of sanitation tanks where the solid parts are filtered out. Chemicals are added to the liquid parts until it's safe to drink and then pumped into the ocean. Bacteria digest the rest of the sludge, which is either loaded offshore or incinerated onboard.

What's happening on... social media?

This month, we asked what are your favourite #lifehacks for keeping cool in the heatwave?

"Wet flannels in the fridge/ freezer! We have several and use them on rotation - been particularly great to cool down at night (as well as using on patches of sunburn!) Wrap in a tea towel if frozen. Plus, to make space I had to eat an ice cream!"
@ginger_post85

"Freeze a 1/3 full water bottle at an angle over night, top up with fresh water in the morning to keep a supply of icy cold water with you."
@Snugglyduvet

"Bowl of ice in front of my fan"
@spanglysparkly

"#lifehacks lots of hot tea paradoxically keeps me cooler!"
@lauragibby1974

"Take a warm shower. After, your body temperature slowly drops and you will feel cooler than you really are. While your hair is wet you will feel cool too. And being clean makes you feel fresh."
@AdamDavidSmith

"#lifehacks got my feet in cold water and keep wetting my hair"
@bev_metallica

Highlights from the Twitterverse

"Did that all really happen? @bluedotfestival"
@ProfTimOB

"Thanks to everyone who squeezed into Mission Control to see me today @bluedotfestival - you were a truly fabulous audience! Have a wonderful rest of the festival. I'm blasting off to Scotland now for another week of filming!"
@theAliceRoberts

"Today we filmed an extraordinary team from @action4ifaw disentangle a 6 month old seal pup from a gill net. She has severe wounds & is now fighting for her life. They are true heroes, a humbling inspiration of what we can do when we are at our best #DrowningInPlastic #CapeCod @BBC"
@lizbonnin

HOW IT WORKS

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FAST FACTS

Amazing trivia to blow your mind

ONCE TWO WOLVES BECOME MATES THEY USUALLY STAY TOGETHER FOR LIFE

THERE ARE OVER

64,200,000KM

OF ROAD IN THE WORLD

1 METRE

THE THICKNESS OF ICE THE RRS SIR DAVID ATTENBOROUGH CAN BREAK THROUGH

THE MAYA CIVILISATION PRE-DATED THE AZTECS AND INCA BY AT LEAST

1,000 YEARS

AMAZON CEO JEFF BEZOS IS AT LEAST

$50 BILLION

RICHER THAN ANYONE ELSE ON THE PLANET

PLANTS USE LESS THAN

5%

OF THE WATER THEY ABSORB

JELLYFISH, METHANE FROM COWS AND USED NAPPIES HAVE BEEN TESTED AS POTENTIAL POWER SOURCES

THE JAPANESE HALCA MISSION CREATED A VIRTUAL TELESCOPE

30,000km

WIDE, EQUIVALENT TO THREE TIMES EARTH'S RADIUS

300 JOULES

THE APPROXIMATE AMOUNT OF ENERGY SENT TO THE HEART FROM A DEFIBRILLATOR

IGUANODONS COULD GROW UP TO 10M LONG AND WEIGH

4,000KG

ANTS EXISTED ALONGSIDE THE DINOSAURS – THEY EVOLVED DURING THE CRETACEOUS PERIOD

22

THE AVERAGE AMOUNT OF PEOPLE PER DAY THE RNLI SAVED IN 2017

THE PANDO QUAKING ASPENS IN UTAH SHARE A SINGLE ROOT SYSTEM THAT SPANS OVER **430,000M²**

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